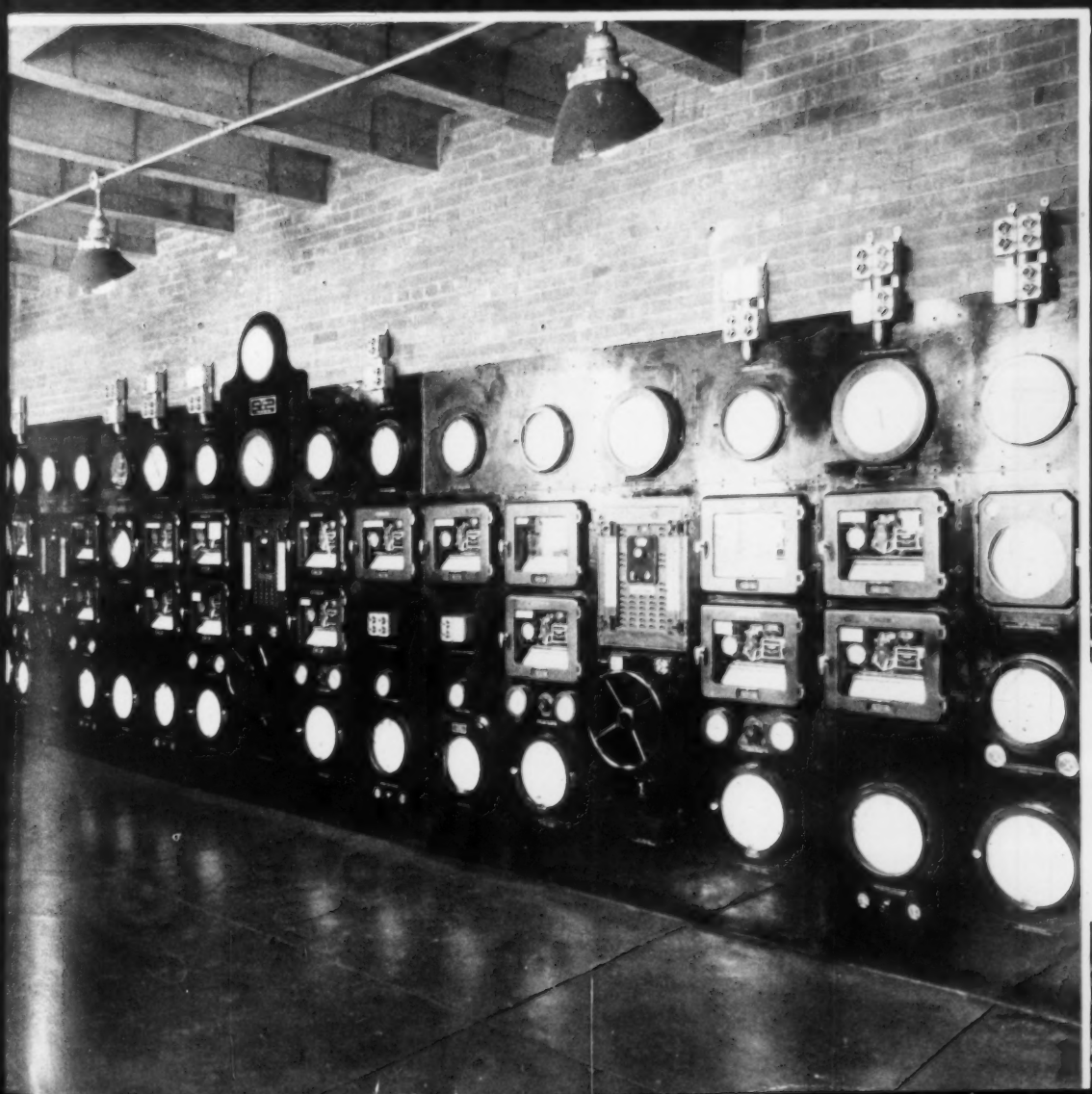
INSTRUMENTS

THE MAGAZINE OF

MEASUREMENT and CONTROL



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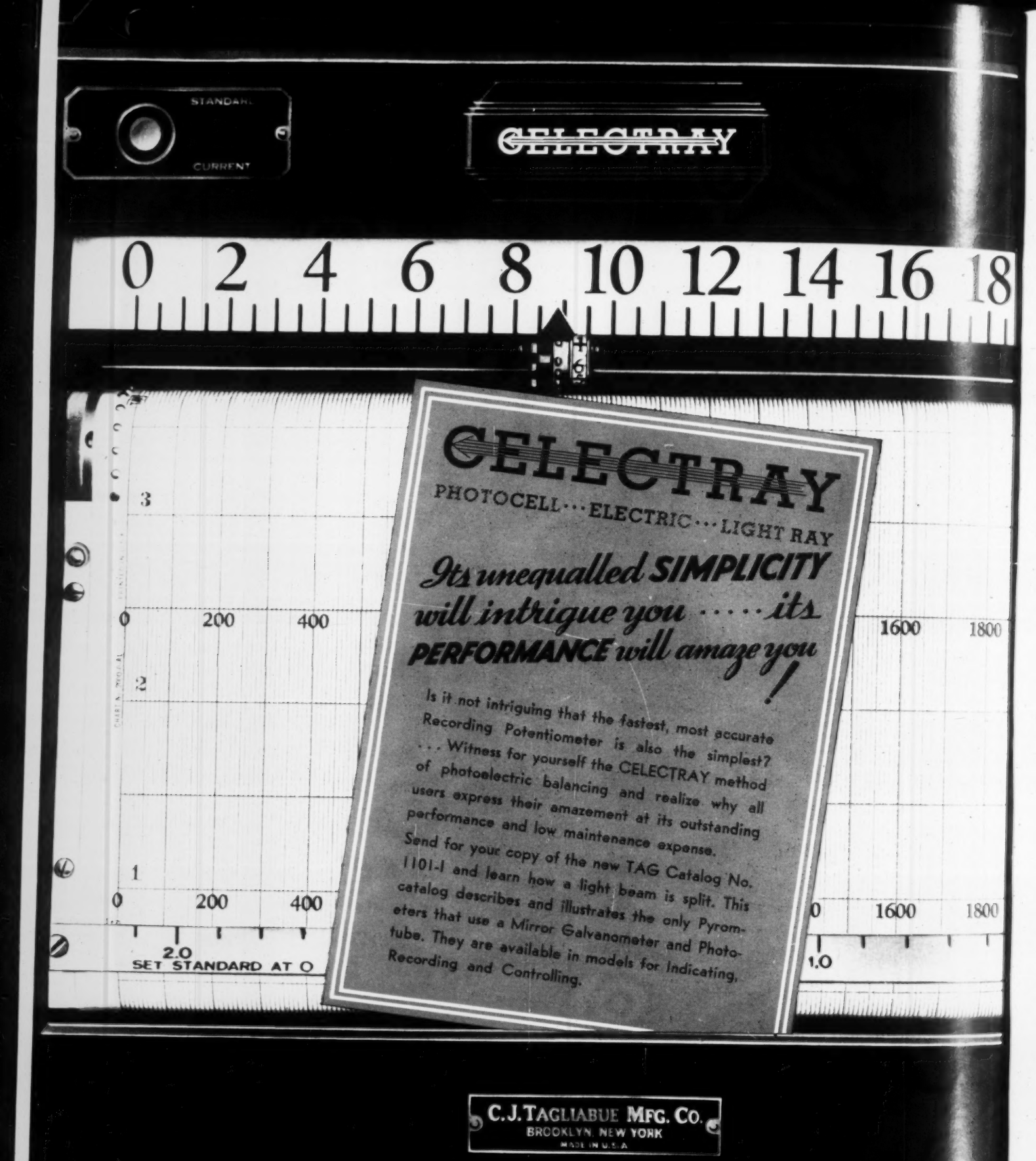
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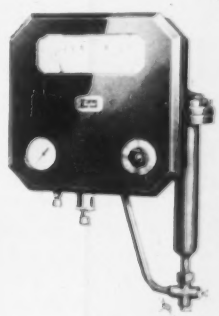
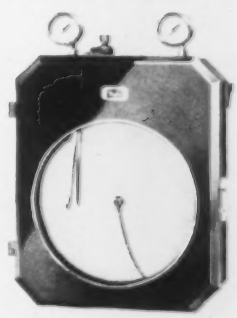


Indicating* Flow and Liquid Level *Controller



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NSTRUMENTS The Magazine of
MEASUREMENT and CONTROL

M. F. BEHAR
EDITOR

IN THIS ISSUE

Two innovations:

1. "Manufacturers' New Literature" Department on a stiff-paper insert with detachable post-card requiring no postage. Yes, it's one added cost in printing and two added costs in postage, but it's well worth it, by reason of the greater convenience to you as well as to our clerical staff.

2. Extra! Feminine invasion of *Instruments*! . . . Well, not quite: this month's "Readers at Work" Department has the honor of dealing with some of our women-readers, but it lacks the charm of personalities, because these ladies demurely insisted on an impersonal, strictly "At Work" report. Come to think of it, though, this very demureness *is* a feminine touch.

Two continuations:

1. "Hardness and Hardness Measurements." Dr. Williams critically reviews and discusses old and new theories of hardness, with special reference to penetration phenomena.

2. "Cathode-ray Oscillography."-Ralph Batcher describes a few more interesting applications—well-known and little-known.

Two inpletions:

1. "New Instruments" Department. Sixteen columns.

2. "*Instruments'* Book Shelf." Nine columns.

THE FRONT COVER

shows still another of those impressive control boards in the oil industry: the Dubbs No. 17 Unit of the Shell Petroleum Corp.

IN TIME OF PEACE

IN our April 1935 issue, under the above title, we departed for once from the field of Instrumentation to deal with the problem of technical preparedness against war. This column concluded as follows:

This huge task cannot be accomplished by the office of The Assistant Secretary without greater support from all industries. Up to now, relatively few manufacturers have assembled the fixtures, gages and other facilities required for change-over; few have devoted sufficient time or encouraged their engineers to devote sufficient time to industrial preparedness.

By the time this is printed, a "war-profit" law will probably have been enacted . . . Get in touch with the nearest Army or Navy technical district office; fill out a list of your qualifications; enroll; and start training! If you prefer joining a 'munitions preparedness movement' without having to enroll in the Army or Navy Reserves, join the Army Ordnance Association (Mills Bldg., Washington, D. C.).

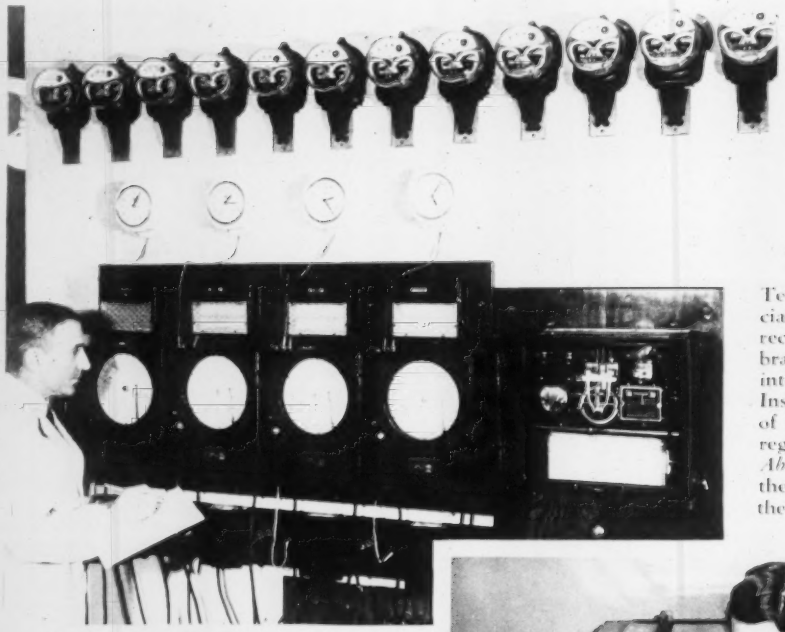
The McSwain bill did pass the House in April 1935, but failed in the Senate. Since then, in spite of the death of Representative McSwain, an even better project—a real "universal service" bill—has been drawn up and has been introduced by Senator Sheppard and Representative Hill, from whose joint statement we quote:

The bill proposes, upon the declaration of war or of a national emergency due to the imminence of war, to authorize the President to determine and publicly proclaim and limit prices; . . . to draft man power between the ages of 21 and 31, subject to such conditions, exemptions, rules and regulations as the President may prescribe; and to take into the military service, as civilians, any persons engaged in the management or control of industrial or manufacturing establishments designated by the President. It also proposes to license those classes determined by the President as necessary for the successful prosecution of war; fix priorities of the filling of orders . . . all in time of war . . . It is our opinion . . . that war should be made a profitless business and that in the event of a future war, a dollar should not be held of greater value than human lives or human suffering. It is also our conclusion that when war ceases to be a profitable business much of the incentive of war will end . . . If fortune should bless us, and there be no more wars, its enactment will not affect the life of the nation. But should war come, we can then meet it . . . promptly and efficiently by a united nation in arms, through equal service from all, and special profit for none.

Citizens who for years have grappled with the complexities of industrial mobilization plans are satisfied that the enactment of this bill would do more to keep America at peace than all the schemes of so-called pacifists whose real aim is to disarm our nation. Its passage seems even more certain than did that of the McSwain bill exactly two years ago, but if it has not passed by the time this issue is in print, patriotic readers will do well to write or wire their Senators and Representatives and, in any event, to join the Army Ordnance Association, the organization "pledged to industrial preparedness for war as our nation's strongest guarantee of peace."

INSTRUMENTS' READERS AT WOR

No. 23 — The Staff and Consultants of GOOD HOUSEKEEPING INSTITUTE NEW YORK CITY



Temperature-controlled hot-rooms, watthour meters specially geared for short intervals, recording wattmeters, recording thermometers of electrical-resistance type calibrated to ¼° F. accuracy and giving readings at 1 min. intervals from sixteen bulbs and check point, enable Institute engineers to make accurate performance tests of refrigerators. Electric clocks operated by series relays register the total operating time of compressor motors. *Above.* In a hot room, a test set is being used to check the starting current of a motor. The leads connecting the resistance bulbs with the recorder may be seen.

Left. The pH value of a soap solution is being measured by a hydrogen ion colorimeter.

Below. This launderometer, consisting of twenty little washing machines in one, is used to check the color fastness to washing of fabrics and the effect of soaps on various fibres.

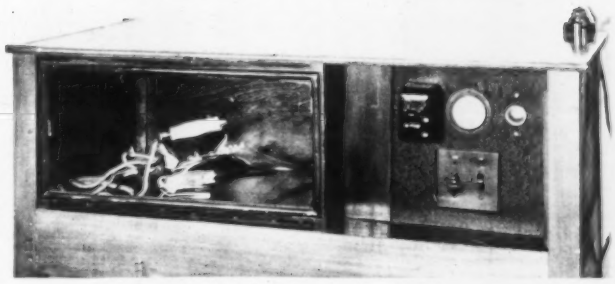
By M. F. BEHAR

IT would not be strictly accurate to say that we introduce on this occasion a group of women readers of *Instruments*, because some members of the group are among our men readers, but the occasion is none the less a notable one. Millions of women take for granted the dependability of products labeled "Tested and Approved by Good Housekeeping Institute." Their faith is well founded: since 1909 Good Housekeeping Institute has functioned as a laboratory in which household appliances, utensils, soaps and cleaners are subjected to searching tests. In addition, the Institute checks the claims of many other kinds of products when these are offered for advertising in *Good Housekeeping*. It is increasingly active in checking textiles for washability, shrinkage, color fastness to sunlight and washing and serviceability generally. Its testing service is conducted primarily for consumers: to help them identify satisfactory products. Manufacturers do not pay to have their products tested, nor are they required to advertise in *Good Housekeeping* to win the Institute's Seal of Approval. Many of them declare that here is an institution where they can get absolutely impartial checks on their own test findings.

Two broad classes of tests are conducted by the Institute: performance tests by engineers or chemists; and "home use" tests by home economists under actual home working conditions. The combined result is both a technical and a "practical" appraisal of design, construction, operating efficiency, safety, convenience of use — in short, of a product's fitness to live up to its claims and do its job well in the hands of its ultimate user.

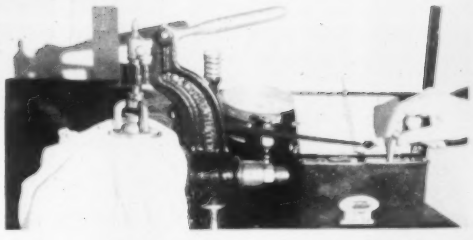
The Director and her associates declined to be "written up" personally but gave us, in lieu of biographical notes, this careful selection of "at work" photographs.

Testing the thermal ef- of an electric smoothing ith a calorimeter of special



Below. By means of an im bedded thermocouple, the sole-plate temperatures of an electric iron are being taken while the iron is in use.

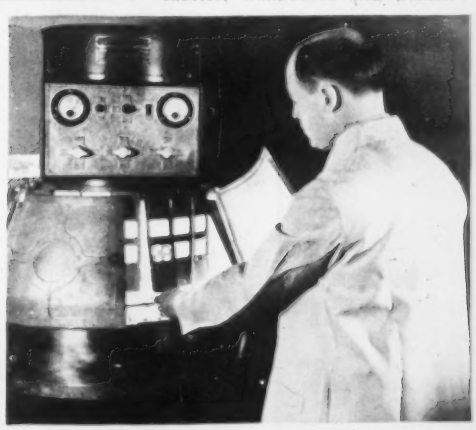
Above. A high-voltage test set of 1500-volt range used for insulation breakdown tests of electrically operated household appliances.



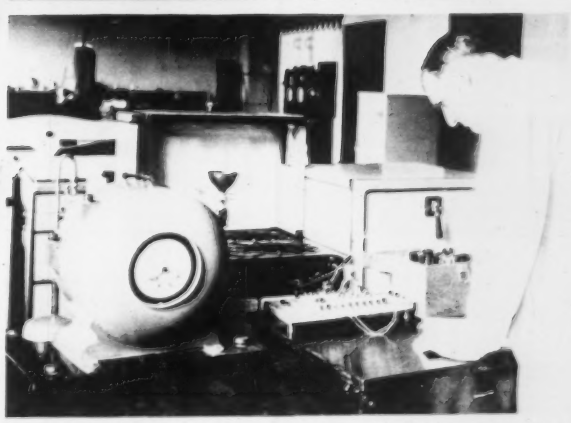
Right. This bursting strength machine is used as one check of the service-ability claims of knitted fabrics.

Below. In this fadeometer the action of ultra-violet rays is used to check claims of color fastness to light of fabrics, wallpapers and paints.

Right. A breaking strength machine similarly checks serv-iceability claims of woven fabrics.

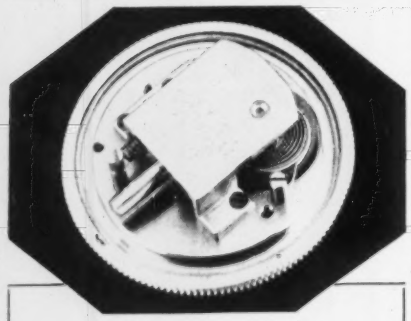


Both the bursting strength and breaking strength testing machines are also used in checking the effect of soap solutions on fabric fibres after repeated washings in the launderometer shown on the left-hand page immediately opposite.



Above. This gas range is having its fuel consumption determined by a portable gas meter, and the performance of its oven regulator checked by a potentiometer.

Left. Temperature readings of an oven are being taken in the course of a standardized baking test.



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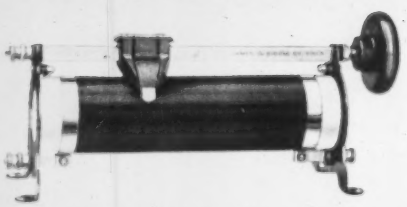

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NEW INSTRUMENTS

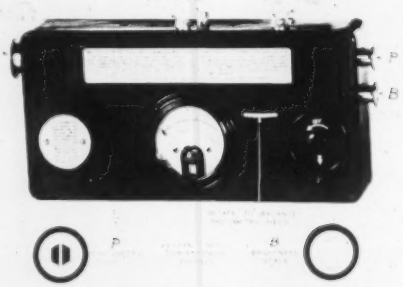
In this department we strive to report each month ALL the new devices for measurement, inspection, testing, metering and automatic control in the form of concise technical descriptions.

When writing to manufacturers directly, please mention this department as your source of information.

Or write to Information Section, Instruments Publishing Company.

Brightness Meter

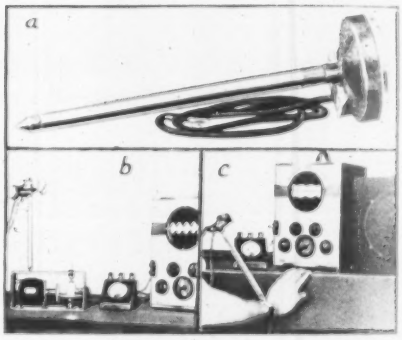
Employing the Bakelite case of the footcandle meter which it supersedes, and weighing 2½ lbs., the Luckiesh-Taylor Brightness Meter has been developed to cover a wide range of brightnesses while meeting the need for a small portable instrument of high accuracy. The sensitivity of the eye sets the lower limit of brightnesses which



can be measured; brightness measurements of the order of 0.005 footlamberts have been made with one of these meters. As to the upper limit, it can be extended as high as necessary; meter illustrated has an upper limit of approx. 50,000 footlamberts but is not designed to measure extremely high values such as of bare incandescent filaments. Meter has two eyepieces at the right-hand end. Through *P* observer views magnified photometric field, consisting of two small silvered rectangles separated by a narrow clear strip. By means of lens tube at opposite end, an image of the object to be measured is brought into focus; brightness of diffusing glass in front of the comparison lamp is varied by circular photographic gradient, and various filters of constant transmission factor may also be inserted when necessary. After photometric balance is obtained, the brightness of the test object is read from a scale seen through and magnified by the lower eyepiece *B*. Values are given both in candles per square inch and in footlamberts. When comparison lamp voltage is set at calibrated value, color of comparison field is approx. same as that of the light from high-wattage tungsten-filament lamps. This is accomplished by a blue filter fixed in position in the instrument. If measurements are to continue over a considerable period of time, voltage drift of dry cells becomes objectionable. To overcome this, terminals permit use of an external source of power such as a storage battery. Accuracy of Luckiesh-Taylor meter is practically constant throughout its working range, except as it may be limited by the color or extremely low brightness of object being measured. Its range is at least 20,000,000 to 1. *General Electric Co., Nela Park, Cleveland, Ohio.*

Crystal Vibration Pick-up

Sufficiently sensitive to pick up vibrations from the escapement of a wrist watch, yet sufficiently rugged to withstand vibrations up to 1/16" amplitude, new Model 156 Sunco Inertia Type Crystal Vibration Pick-up employs a bimorph crystal mounted inside the aluminum case and having no direct mechanical connection with the prod. When the case (which weighs only 4 oz.) vibrates, the crystal flexes of its own inertia and sets up voltage impulses of the same wave form as the mechanical motion. Response is practically linear up to the resonant frequency of 2,500 cycles. Output sensitivity is 2 volts r.m.s. with 0.001" motion at 100 cycles per second. An 8" duralumin test prod is provided. Model 156 Pick-up is designed to be used in connection with maker's Model 150 Neobeam Oscilloscope (see *Instruments* Nov. 1936, page 343) which has a built-in amplifier and a voltmeter on the output, to determine the



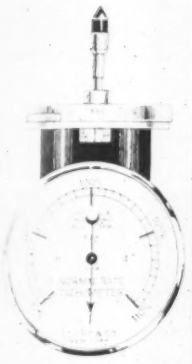
frequency, amplitude, and velocity of vibration. Since voltage output of the Model 156 Pick-up varies as square of velocity, and vibration energy also varies as square of velocity, the voltage, as read from output of Neobeam Oscilloscope amplifier, is a direct function of the energy. Extremely small vibrations such as watch ticks, etc., are made audible with the speaker attachment shown in Fig. *c*. Applications include production testing of electric motors (Fig. *b*), ball bearings, crankshafts, gear trains, fans, etc., locating source of vibration in reciprocating or rotating machinery, checking relative smoothness of surfaces, relative efficiency of materials for deadening sound. *Sandt Engineering Co., 2258 Lincoln Ave., Chicago, Ill.*

Oscilloscope Condenser Kit

A convenient kit of the capacities called for in the construction of the new Thordarson Cathode-ray Oscilloscope comprises 18 units of various types, capacities and voltage ratings. *Aerovox Corp., 70 Washington St., Brooklyn, N. Y.*

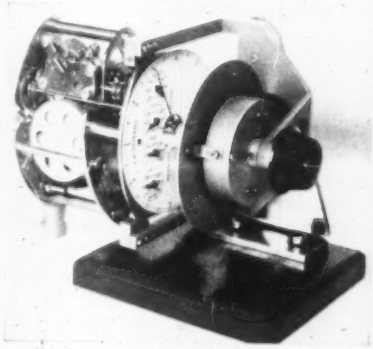
ormal Rate Tachometer

end of indicating r.p.m. over a scale range (and hence with a low e of precision) this entirely new of hand tachometer indicates departure from normal speed over a scale graduated from 90% to 110% in 0.5% divisions and readable by estimation to 0.1%, *i.e.*, to 1 r.p.m. when normal speed is 10,000 r.p.m. Thus, "Standeo Normal Rate Tachometer" may be termed a percent limit" tachometer. Its principal applications being in electrical engineering, the first two models announced are for speeds related respectively to (1) 25- and 50-cycle systems, and (2) 50- and 60-cycle systems. Each model has six ranges. "No. 500" is for normal speeds of 750-1000-1500-3000-4500-6000 r.p.m.; "No. 501 American Model" is for normal speeds of 1000-1500-3000-1200-1800-3600 r.p.m. Gear attachments, however, permit obtaining 22 different normal speeds with the No. 500 and 32 with the No. 501. Net weight approx. 1¼ lb. Furnished with accessories in case measuring approx. 11⅞" × 6¼" × 3⅞". *Herman H. Sticht & Co., 27 Park Place, New York City.*



Portable Meter Torque Tester

New portable torque testing device has been designed for measuring clutch and demand pointer friction on Types RW and DR demand registers. Means are provided in these registers for making adjustments and the new device facilitates making these adjustments. Its essential element is a calibrated spiral spring, inner turn of which can be rotated by a shaft provided with an adjustment knob carrying an index, outer end operating (a) a finger applied to the register maximum demand pointer or the push finger and (b) a dial graduated in centimeter-grams. Demand registers, when removed from the meter, can be tested by placing them in the torque tester mounted on its supporting stand. Demand registers installed on meters can be tested by new device removed from its stand. A similar tester for testing Type RW-2 demand registers can also be supplied. *Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*



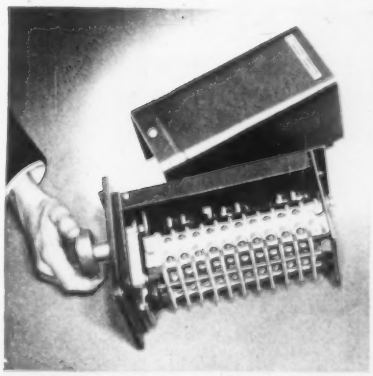
Gas Calorimeter

To provide smaller gas plants with an economical means of measuring the calorific value of the gas they produce, maker has designed a junior model calorimeter, the "Thermeter," with overall dimensions 21" × 23" × 17". It consists of (1) tank unit or calorimeter where heating effect of the gas is measured, and (2) recording instrument for translating the heat measurement into B.t.u's per unit quantity of gas independent of variation in temperature, pressure, and humidity.

Heating value is determined by imparting the heat from combustion of test gas to a mixture consisting of excess air and products of combustion, and then measuring temperature rise of mixture. Streams of test gas and air are supplied to the burner in fixed volumetric proportions by metering devices geared together and driven by a motor. Proportions are fixed at the same temperature, pressure, and humidity. Thermeter recording unit is a L. & N. round-form self-balancing potentiometer recorder with a special measuring circuit, suppressed zero type, indicating only active range from 300 to 600 B.t.u.'s, and recording it on 24-hour, 10" diameter charts. *Cutler-Hammer, Inc., 312th & St. Paul Ave., Milwaukee, Wis.*

Rotating-cam Switches

New "CR3300" line of rotating cam switches is designed especially for built-in control applications but, for non-built-in applications, the devices are available without the flanges used for flush mounting. The new line comprises a number of electrical and mechanical modifications. Two sizes are available. Size 0 (illustrated), rated 15 amps. continuous, and Size 1, rated 25 amps. continuous, both for 600 volts or less, a.c. Special sequences, and forms with off position contacts, are available. *General Electric Co., Schenectady, N. Y.*



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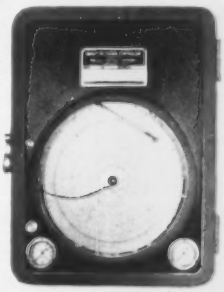
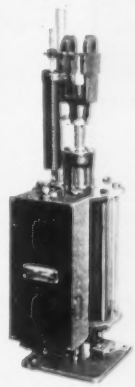


Recorder-Controller

Boiler Meters for recording combustion conditions and guiding boiler operators. Described in Bulletin No. 44.

Multi-Pointer Gages for indicating factors such as draft, pressure, temperature and speed. These Gages are available with any number of pointers and any scale combination; in either the oil sealed bell or diaphragm construction.



Control Brace

Flow Meters for indicating, recording and integrating the flow of steam, water, sewage, air, gas and other fluids. Bulletins No. 39 and 300.

Recorders for pressure, temperature, drafts, liquid level and other factors.

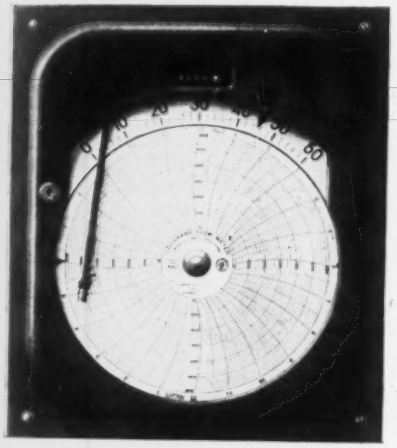
G-3

BAILEY METER COMPANY

1041 Ivanhoe Rd., Cleveland, Ohio

COCHRANE FLOWMETERS

Accurate — Sensitive — Rugged



Adaptable to industrial service wherever the flow of steam, water or other liquids or gases is involved, Cochrane Flow Meters are sturdily built and extremely sensitive to variations in flow.

Recorders of both the Electric and the Mechanical models are guaranteed accurate within one-half of one per cent of absolute under full load.

Cochrane Electric Flow Meters operate on the super-accurate galvanometer null principle. They may be installed at any distance from the pipe line, facilitating central panel grouping.

Send for complete information

COCHRANE CORPORATION

3120 North 17th Street, Philadelphia, Pa.

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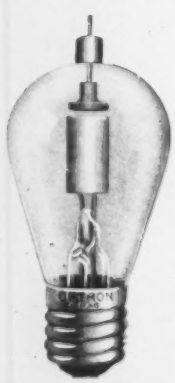


Filament Voltage 2 volts
Filament Current 13 volts
Output 6 Amperes

2000 Hour Guarantee

Type 2-RA-6

Different in design—more efficient in operation—longer life—the 2-RA-6 offers a new conception of rectifier bulb performance and efficiency!

Write today for technical bulletin MR-1

CONTINENTAL ELECTRIC CO.

Geneva, 2, Illinois

PHOTOCELLS VACUUM GAUGES

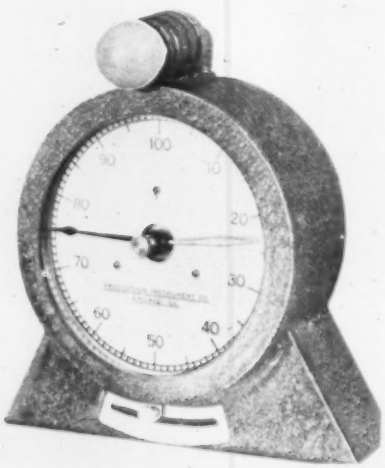
Direct-reading Analyzer

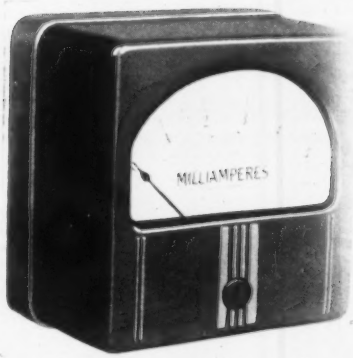
In addition to offering an unusually complete array of a.c. and d.c. voltage ranges, new "Model 95 Super Universal" has direct reading capacity scales to cover all values from 0.00005 to 16 mfd. Resistance ranges cover values from 1 ohm to 20 megohms. Complete list of voltage and current ranges is as follows:

d.c. volts, 0-5-50-500-1000; d.c. ma, 0-50-500; a.c. volts, 0-8-40-160-400-800, plus five resistance ranges and three capacity ranges. Two 4½" fan-type instruments with CB green molded cases are used. Their scale length is said to equal or exceed that of any other analyzer. All a.c. and capacity ranges, with their selector switches and binding posts, are segregated on a separate panel, while the other panel contains a duplicate instrument, selector switch, and pair of binding posts for the a.c. voltage, current, and resistance ranges. This simplifies scales and switching mechanism. It is claimed that this 21 range analyzer is less complicated in operation than the ordinary pocket volt-ohmmeter. Operation is from a built-in power supply. Model 95 is offered in both portable and 10" relay rack mounting types. *The Classic Triangle Co., 284 W. 79th St., Chicago, Ill.*

Production Timer

Developed for timing shirt-finishing operations in laundries, new model of "Production Guide" is likewise applicable to other steadily repeated operations or processes wherein definite and uniform timing of certain time elements is desired. Various speeds can be provided. Any proportion of loading time and working time can be arranged. In addition to a signal light or bell, a solenoid operated release for a press or other machinery can be operated by the Production Guide. *Production Instrument Co., 1425 South Wabash Ave., Chicago, Ill.*



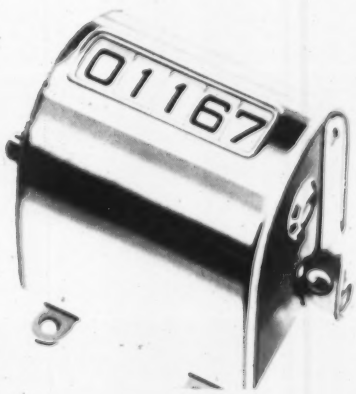


Miniature Panel Instruments

A new line of round and rectangular design miniature instruments, designated as Type 35, available in a.c., d.c., rectox and radio-frequency types, includes thermometers, milliammeters, microammeters, voltmeters, millivoltmeters, power factor meters and volt-ohmmeters. For use in all industrial and radio applications in a variety of forms, entire line employs but two types of movements to provide interchangeability of parts and permit short delivery schedules on special and semi-standard forms. Movements are of new improved design having higher torque-weight ratios and low volt-ampere burdens. Ranges as low as 20 microamperes in moving-coil types, and self-contained ammeters of 50 amps and voltmeters of 200 volts, are all available in new line, which thus provides economical maximum in variety of ratings with minimum of external accessories. Instruments are rated at 750 volts which corresponds to a test of 2500 volts between terminals and panels. Special capacities and special dial markings may be supplied to meet specific applications. Portable housings for use with round type instruments are available. *Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.*

Stroke Counter

Illustrated herewith in its actual size, new "SMC-1" mechanical stroke counter for built-in applications on small machines has a capacity of 99,999. Its overall dimensions are 1⅞" x 1⅞" x 1⅝". Case is brass, cadmium plated. Lever throw is ½". Action is positive; forward stroke brings next figure into complete, legible position, and "skips" are prevented. Counter is available with operating arm on either right or left hand side of case. *Production Instrument Co., 1425 South Wabash Ave., Chicago, Ill.*



Six-inch A-c. Surface-mounting Switchboard Instruments

New 6" square-case switchboard instruments are available in a-c. voltmeters, ammeters, wattmeters, polyphase wattmeters, synchroscopes, frequency meters and power Factor meters. Wattmeters have uniform scale electrodynamometer movements. Others employ a new movement said to be a new development in magnetic vane instruments resulting in scales which are nearly uniform from 1/5 to full scale. Cases are all steel, thus completely shielding movements from influence of stray fields. Mounting is either front-of-board or flush. All models are damped approx. 95%; all are equipped with external zero adjuster insulated from electrical circuit of instrument.—*The Hickok Electrical Instrument Co., Cleveland, Ohio.*

Automatic Moisture-content Control System

"Moist-o-graph" control system for installation on slashers sizing cotton warp yarns consists of (1) stainless-steel detecting roll and insulated bracket, (2) power unit, (3) Moist-o-graph recorder, (4) final control mechanism: a valve for steam supply line or a variable-speed unit. Yarn moisture is continuously measured at delivery end of slasher by measuring electrical resistance of yarn between the back-press roll and "detecting roll," both of which make dependable contacts with yarn. There is no electrical hazard. Power unit and recorder are furnished with dust-proof die-cast aluminum cases suitable for universal mounting and each provided with a lock. A-c. supply is required for power unit. Electrical connections are made to detecting roll, recorder and frame of slasher. Moist-o-Graph is not affected by variations in line voltage and it is said that successful operation is secured despite dust, vibration and excessively high humidities found in many mills. Recorder scale, calibrated from 4% to 10% regain for cotton, is mounted directly above recording pen. Percent regain is recorded on a 12" visible strip chart. Recorder is available for either electric- or air-operated control systems; a control valve may be used to regulate the steam supply, or a suitable variable-speed drive may be selected for the automatic control of speed. The moisture in cotton warp yarns can, therefore, be easily controlled at 7% or 8% regain for perfect weaving. *Brown Instrument Co., 4485 Wayne Ave., Philadelphia, Pa.*

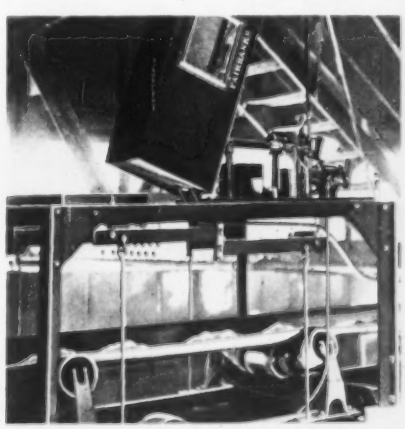
Illuminated Weightograph

A new model of the "Weightograph" described in our March 1931 issue, pages 290-291, has been developed in which the

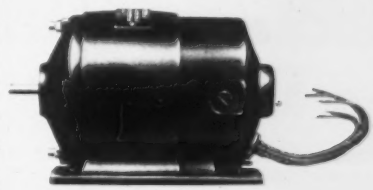
figures appear on an illuminated dial readable from across a room and from "any angle." *The Howe Scale Co., Rutland, Vt.*

Conveyor Scales and Remote Recording Features

Continuous weighing of wet or dry material, flowing at as low a rate as 1 lb./ft. or in greatest quantities met with in industrial applications, is accomplished by a deflection-operated positive-action integrating mechanism in dust-proof case located above conveyor belt and in no way interfering with manufacturing routine. System permits remote installation of various types of instruments. Thus, the installation of which illustration shows only the weighing mechanism comprises also a three-pen electric time recorder (Bristol Co.) 250 ft. from the scale and a five-dial tonnage register likewise remotely located. *Fairbanks, Morse & Co., 900 So. Wabash Ave., Chicago, Ill.*



REMOTE INDICATION *and* CONTROL



. . . is usually a job

for AUTOSYN SELF-SYNCHRONIZING MOTORS!

TYPE 1 AUTOSYN MOTOR is a reasonably priced self-synchronizing motor with superior performance characteristics. One transmitter may operate as many as six receivers. Practically any system of remote indication or control may be solved by the selection of the proper type of Autosyn Motors.

FEATURES:

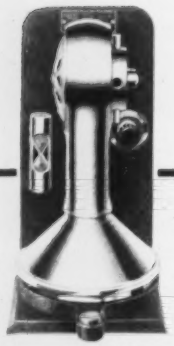
1. Conventional Motor mounting interchangeable with most standard self-synchronizing motor elements.
2. Approximate accuracy: Two degrees.
3. Maximum torque 14.8 inch ounces.
4. Safe continuous operating torque 5.6 inch ounces.
5. Brushes carry no current during synchronism.
6. Enclosed inertia dampener reduces oscillation to maximum of 3 seconds and is adjustable to suit.
7. Dimensions: 3-5/8"x3-9/16"x5-3/4".
8. Weight: 5 lbs., 12 oz.
9. Low current consumption and temperature rise characteristics.
10. Voltage range for accurate and safe operation, minus 20% to plus 10% normal rating.

Complete information on request.

BENDIX MARINE PRODUCTS CO., Inc.

(Subsidiary of Bendix Aviation Corporation)

754 Lexington Avenue
Brooklyn, N. Y.



MOISTURE
Content by Drying

The Moisture Teller as illustrated above will dry 50 or 100 gram test samples at the rate of one per minute. Test samples are weighed before and after drying to obtain moisture content in percentage.

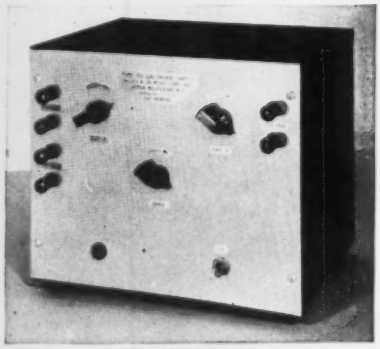
Used in the following industries: Foundry — Paper — Mining — Rubber — Milling — Textile — Tobacco — Food — Brick, etc.

Rapid and accurate moisture test for either laboratory or shop moisture control.

Write for Literature

Harry W. Dietert Co.
9330 Roselawn Avenue
Detroit, Michigan

SIMULTANEOUS OBSERVATION ALLOWS TRUE COMPARISON WITH THE DU MONT TYPE 150
ELECTRONIC SWITCH



This instrument when used in conjunction with a Cathode Ray Oscillograph vastly increases the value of the Oscillograph.

It allows: Simultaneous observation of any two phases of current phenomena inspection and comparison of wave form or phase of two voltages or currents from different parts of the same circuit; comparison of wave form of a standard wave with another wave; it can be applied to a timing wave in conjunction with the wave under observation.

Unit is self-contained and operates from 110-120 volt, 60 cycle current. Controls are provided for adjusting gain of amplifiers and for varying the speed of switching.

Frequency Range 10 to 500,000 c.p.s. Gain of Amplifier in Audio Frequencies—30. Power consumption—30 watts.

Write for complete catalogue of Du Mont Cathode Ray Tubes, Oscillographs and accessory apparatus.

ALLEN B. DU MONT Laboratories, Inc.
532 Valley Road — Upper Montclair, N. J.

Filter Attachment for Direct-reading Anemometer

In "Boyle Velometer" (see *Instruments*, July 1935, page 191), air stream passing through instrument tilts a vane provided with restraining spring and damping system. To permit use of this anemometer in air laden with ordinary dust or magnetic dust, a filter attachment has been brought out which can be used with or without the tube, tube fittings and jets (see *Instruments*, Dec. 1935, page 343; July 1936, page 177) depending upon velocity range and requirements. Instrument can be scaled for direct reading with filter attached, or a conversion chart is furnished when it is to be used both with and without filter. *Illinois Testing Laboratories, 142 W. Austin Ave., Chicago, Ill.*

Standardized Sieve-shaking Tester for Cements, etc.

A new model "End-Shak" testing sieve shaker, for testing fine materials, is provided with a simplified hold-down device which permits the sieves to be quickly put in place and removed, regardless of number of sieves used. Combined reciprocating and turning motion of this shaker carries out methods employed and recommended by the National Bureau of Standards in making standard cement tests: about 150 strokes per minute, revolving the sieves approx. 1 r.p.m. No strenuous motion is applied to the sieve—simply a light tap at the end of each stroke by the free hand. This allows material to roll over sieve cloth, keeping it in constant contact and giving it every possible opportunity to find an aperture through which to drop. This action causes sample to spread uniformly so that 100% of the sieve surface is continually utilized. Sample material does not pile up and leave a large area uncovered; there is no jumping or bouncing of particles, nor any sudden jerking of the sieves from under sample in such a way as to make it impossible for particles to pass through sieve. Operation of "End Shak" machine is said to be exceptionally smooth and quiet. Nest of sieves reciprocates in a direction lengthwise of the gear box. Mechanism is entirely enclosed, as shown, and operates while submerged in oil. A time switch automatically controls period of test. Machine is designed for 8" diameter testing sieves, holds any number of sieves from 1 to 8, weighs 145 lbs. including motor and automatic time switch, is 32" high. A standard ¼ h.p. motor is used; 110 and 220 volt 60-cycle supply; 1750 r.p.m. Special motor equipment if desired. *New Wire Cloth Co., Newark, N. J.*

Improved Davey Portable Balancing Equipment

Several improvements in the design of the Davey Portable Balancing Equipment are announced. Illustration shows complete equipment for power plants

This is suitable for the balancing of large turbines and also for auxiliary machines such as fans, exhausters, pumps and motors. In addition, photographic feature of "two-direction" Vibrometer enables records of turbine vibration to be made periodically, which often leads to discovering troubles before they become serious. Model-82 Vibrometer, which measures in two directions simultaneously and also indicates wave form (see *Instruments*, Aug. 1932, page 193), is shown at right of illustration; and "single direction" Model-1 Vibrometer is shown in foreground center. These two Vibrometers may be used interchangeably. Model-3 Stroboscopic Lamp (with three neon tubes) is shown at left. In left foreground, the Breaker Head and phase adjuster is shown coupled to the Synchronous Motor Unit. This synchronous motor unit is a new feature used for balancing 60-cycle machines running at 3600, 1800 or 1200 r.p.m. By its use, it is unnecessary to couple breaker head to shaft of the machine; and the motor and breaker head may be placed at any point most convenient to operator. For machines running at other speeds, breaker head is driven from end of shaft by a tachometer point. Where maximum portability is required, a balancing equipment with single neon lamp is available. *The Electrowon Corporation, 6 Varick St., New York City.*

Photoelectrically Balanced Recording Potentiometer

improved form of the recorder first described in *Instruments*, March 1934, p. 58, is being introduced as the "Speedray." Original instrument had a system of synchronized shutters and electric contacts serving to detect direction of beam of light reflected from a mirror galvanometer toward a photocell. This system has been eliminated together with one of three relays and an electromagnetic brake, leaving but two relays and a reversing motor in this circuit; but the resistance and high-sensitivity recording galvanometer is retained. Fundamental problem of stopping a moving light beam on the edge of a photocell without tendency to oscillate or "hunt," and yet with speed and precision, has been solved by (1) applying an advancing emf. to the galvanometer while it is deflected, (2) using electromagnetic relays (not electronic) to separate potentiometer and electronic circuits, and (3) delaying action at far edge of dead zone when entered by light beam, by delaying response of amplifier at the balance point. These improvements enable balancing "with an accuracy of a few hundredths of one percent" at a speed corresponding to 15 sec. for travel of the whole (10") scale. At higher speeds, accuracy of balancing is proportionally reduced.

Balancing Power Circuit includes only reversing motor and control contacts on two relays (Fig. 1). With both relays closed, reversing motor drives moving contacts of slide-wire potentiometer downscale, and *vice versa*. With relay 1 closed and relay 2 open, motor stops.

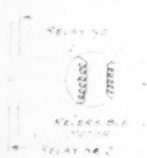


Fig. 1

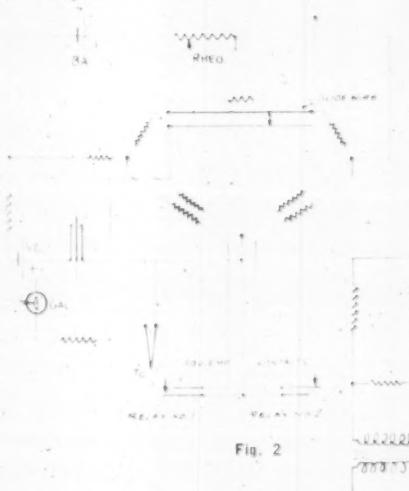


Fig. 2

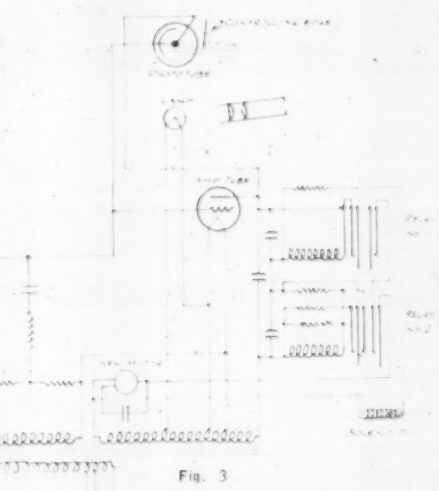


Fig. 3

Potentiometer circuit includes a nickel coil for automatic reference junction compensation. Galvanometer is connected directly to slide-wire contacts in order to make possible recording the standard current as in previous models. Extra connections for relay contacts (Fig. 2) are used to apply the advancing emf. whenever the relays are both open or both closed. At the balance point, connection is made to the correct point corresponding to compensated zero of scale, *i.e.*, when relay 1 is closed and relay 2 open.

Photoelectric circuit (Fig. 3) includes (1) essentially: phototube, lamp, amplifying tube, coils of both relays, transformer; (2) incidentally: synchronous capacitor motor and recording solenoid. Each relay shunts its own coil on closing, so that current through its coil is immediately reduced to a value near opening current. Operating and releasing time of each relay is controlled by these shunt resistors and shunting capacitors as shown. Grid circuit of amplifying tube includes a capacitor and resistors which furnish a "time delay relay" action. Relay 1 can close quickly and relay 2 cannot; and relay 2 can open quickly and relay 1 cannot, under conditions met with as the light beam swings to and fro across the "controlling edge" at the phototube.

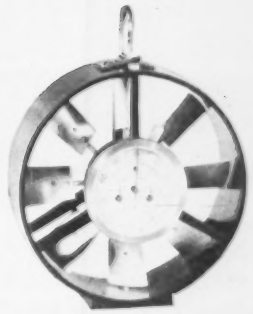
Galvanometer is thus "trapped in the normal position," with relay 1 closed and relay 2 open, each having a delayed tendency to act, if the light beam is deflected. Vibration is harmless and a deflection must persist to have any effect. The application of an advancing emf. makes it possible to use a heavily damped galvanometer with a large back emf. In multiple-point recorder, contact carriage travels asymptotically to each new point. Dead zone, corresponding to deflection of light beam required to raise plate current from opening value of relay 1 to closing value of relay 2, is 0.2 of width of light beam at controlling edge, but is not obtained with critical relay adjustments, this relay differential exceeding possible changes in relay operating currents. Sensitivity of standard galvanometer is sufficient for scale ranges well below 10 mv. and controlling edge is offset from vertical except for special low ranges. Special galvanometers are available for ranges of a few millivolts.

Recording and Commutation Mechanisms. When light beam has stopped at normal point a sufficient length of time, solenoid (Fig. 3) is released. A swinging link then engages an eccentric pin on a disk driven by the synchronous motor. Link is attached to commutating switch drive lever. Movement of switch and lever results in a single recording operation. Once in every 192 records a switch substitutes the standard cell, forcing instrument to record the standard current.

Interval Between Records varies from 3 sec. between records of identical temperatures to 50 sec., averaging between 10 and 15 seconds in most cases.

General. Many features (hardened gold contacts, etc.) described in March

FRIEZ



FRIEZ BALTIMORE

Anemometers

In standard types will determine air movement from seventy-five feet per minute, and in special types as low as fifteen feet per minute.

Can be used for either horizontal or vertical measurements. Designed especially for air passing through or from ducts, flues, grilles, or fans.

Two Types

BIRAM—with readings in linear feet convertible to velocity by time division.

DIRECT READING—on accurate dials in feet per minute, without need of tables or calculations.

● ACCURATE
● RUGGED
● RELIABLE

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Test this thermometer yourself. Order one today.

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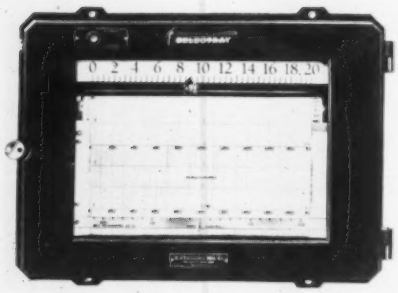
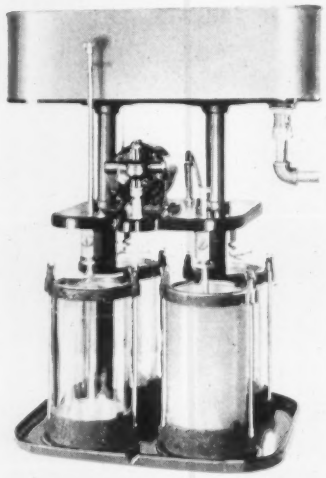
Branch Factory: 93 Church St., Toronto, Can.



1931 is we are retained. Among new features, a voltage regulator of unique type prevents dead zone shift in event of even a wide fluctuation in line voltage. Celectray is available in numerous forms of recorder-controllers, recorders and indicating-controllers, for resistance thermometers as well as thermocouples and other electric devices. *C. J. Tagliabue Mfg. Co., Park & Nostrand Aves., Brooklyn, N. Y.*

Clay Washer

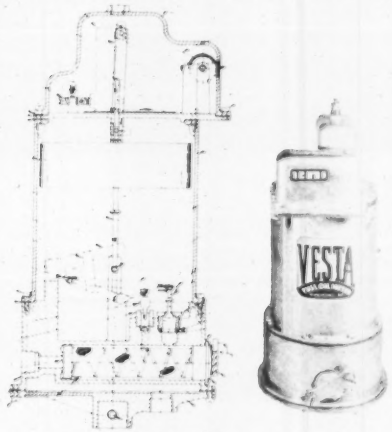
For determining the clay content of molding sand, new No. 545 Clay Washer is used for washing the A. F. A. clay substance from molding sand after sand has been agitated with maker's Rapid or Rotating Sand Washer. Its specifications are: Net weight, 70 lbs.; height, 24"; base, 12½ × 14"; motors, 110 or 220 volt d.c. or single phase a.c. Four samples may be washed at one time. Wash bottles with removable bottoms are furnished so that the clay-free sand grains may be



removed from wash bottles without filtering and dried in oven. Washer consists essentially of a base receiving the four wash bottles; two supporting posts with a table on which is mounted the motor and drive mechanism to rotate the four washing tubes immersed in the sand sample; a water tank containing a float valve to maintain a constant level of water in tank. A thermostatic heater maintains a water temperature of 75 F. Distilled water is recommended for research tests, tap water may be used in certain localities for control tests. Float valve will operate against water pressure up to 75 lbs./in.². *Harry W. Dietert Co., 9330 Roselawn Ave., Detroit, Mich.*

Fuel Oil Meter

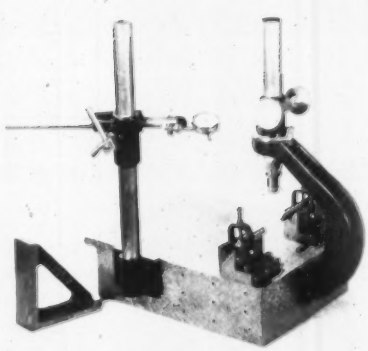
For all gravity installations, where top is lower than bottom of supply tank or of wall pump, and where flow does not exceed 8 g.p.h., this new inexpensive integrating "Vesta" meter will



register the volumetric consumption of fuel oils known as Nos. 1, 2, 3 or 4 or of Diesel oils within a wide viscosity range. Unit of registration (last digit on counter) is 0.1 gallon; non-reset counter (Veeder-Root) registers to 9999.9 gals. and repeats. Connections are ⅜" s.p.t. Meter is of positive action; float actuates inlet and outlet valves to measuring chamber, as well as cyclometer register. Height, 12"; weight, 9 lbs. *Fluid Meters, Inc., Chrysler Bldg., New York City.*

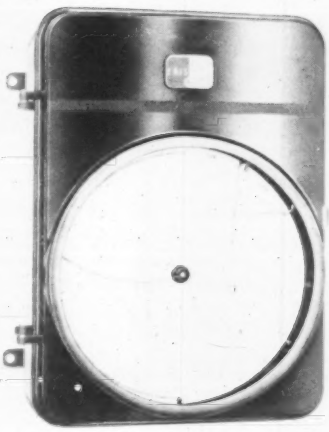
Three-Angle Surface Plate

A surface plate made for manufacturer's own use has been found so useful as a base element for checking mechanical parts with dial indicator, microscope, and height gage that it is now offered as a standard product. Top surface is 9" × 12"; height, 3". The three surfaces are scraped flat to 0.0001" and the three angles are 90° within 0.00025" in the 12" length. One of the 3" faces can be used as a base with a larger plate to form an extremely accurate right angle member or flat plates can be clamped to it to build up right angles on its 9" × 12" surface. Illustration shows plate with some accessories. Microscope and its mounting arm permit viewing small parts; vee rests and centers offer easy methods of assembling parts to be checked. Another feature consists in regularly-spaced 10-32 holes in top and sides. These spaced on 2" centers permit clamping of fixtures and accessories to surface. *Mica Instrument Co., Cambridge, Mass.*



ound-chart Potentiometer

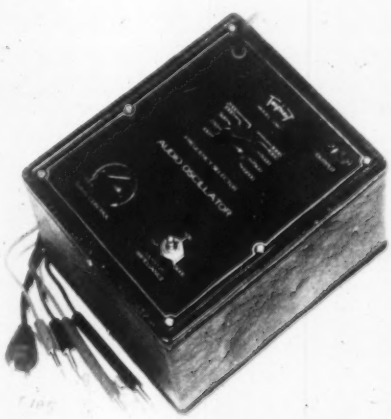
new recording potentiometer of d-chart form, known as the Pyro- er, has been made available as a meter, tachometer, resistance ther- meter, millivoltmeter and milliam-



meter. It is said to "operate on an entirely different principle, which makes possible a number of very important exclusive features." It is claimed to require no lubrication and to be unaffected by normal plant vibration. There is no mechanical motion except when a change in the measured value takes place; and instrument can be used where the air is "laden with dust, moisture, and corrosive fumes." Operating mechanism is made up of five small replaceable units, without mechanical connections between galvanometer unit and other units; is housed in maker's standard Model 10M case. Chart size is 12". *The Bristol Co., Waterbury, Conn.*

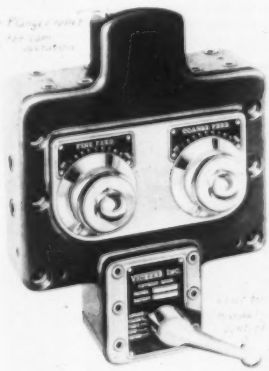
Audio Oscillator

New portable Model 1260 Audio Oscillator generates a sine wave said to be pure and free of distortion and harmonics. It is a.c.-operated. Frequency range of the instrument is 100-250-500-1000-2000-3000-4000-5000-7500-10,000 cycles. The signal furnished is sufficiently strong to be used successfully in checking weak amplifiers. Attenuation for the measurement of gain percentage is said to be extremely accurate. Impedance matching is variable. Circuit is the familiar feed-back type. Metal case with black wrinkle finish is 7¾" × 6¾" × 4¾". Panel is silver and black. *The Triplett Electrical Instrument Co., Bluffton, Ohio.*



Hydraulic Controller for Machine Tools

New "Series C2-1237" feed control panel for machine tools is applicable to drilling, reaming, boring, turning, milling, and equivalent machine tool cycles; will provide any cycle sequence, as made up of rapid advance, adjustable coarse feed, adjustable fine feed, and rapid return motions. Main internal control valve is actuated by one of three interconnected means: manually by lever shown, mechanically by trip cams on moving platen or head contacting the plunger roller shown, and electrically by energizing solenoids separately mounted behind the unit. Starting of cycle into rapid advance can be accomplished by manual



movement of control lever if panel is convenient to operator's station, or remotely by push button or other electrical contact means. Change from rapid advance to feed is normally accomplished by a cam or cams contacting the plunger roller at desired points. If two feed rates during the cycle are required, the first cam usually depresses plunger to correspond with "coarse feed" valve position and another depresses to "fine feed" at the proper time. When only one feed rate is required, other may be completely disregarded. Should a rapid traverse be required between feeds, as in a jump feed cycle, a hinged hook cam can be provided for pulling valve plunger back out to "rapid advance" position, and another conventional type cam employed to return it again. When end of forward stroke is reached, a limit switch or pressure switch must be actuated. This energizes a solenoid causing main valve on panel to be shifted to "rapid return" position. If a dwell at end of feed stroke is desired for machining to accurate limits against a solid stop, reversing limit switch or pressure switch starts an electric timer in the circuit which in turn energizes the reversing solenoid at end of a predetermined dwell period. An automatic stop action after the return stroke is obtained by hook cam pulling plunger back to the "stop" position. Pump is then unloaded by allowing oil to circulate at no pressure, continuing to operate at no load until succeeding cycle is started. Hydraulic circuit in the panel employs Vickers Feed Control Valve and "locked circuit" combination. Design is such that there are but two moving parts—main control valve and feed compensator, both completely and positively pressure lubricated by the oil in the system. All hydraulic operating equipment for a normal application is included in the one unit, except pump and pressure control. —*Vickers, Inc., 1400 Oakman Blvd., Detroit, Mich.*

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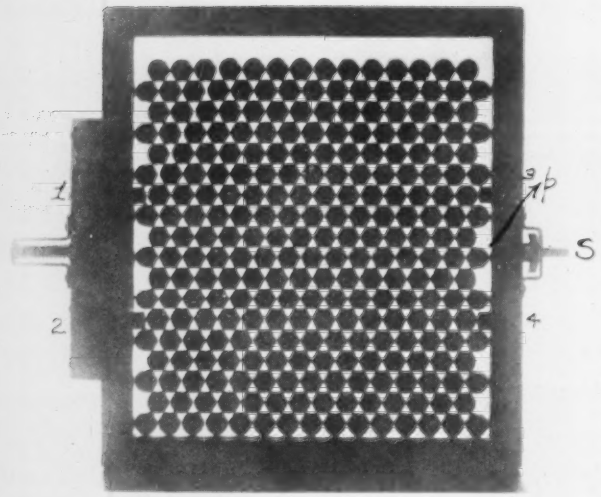


Fig. 24 (a). The balls are arranged in "normal piling" in the undisturbed condition.

Diffraction effects make the balls appear as hexagonal disks against the illuminated background.

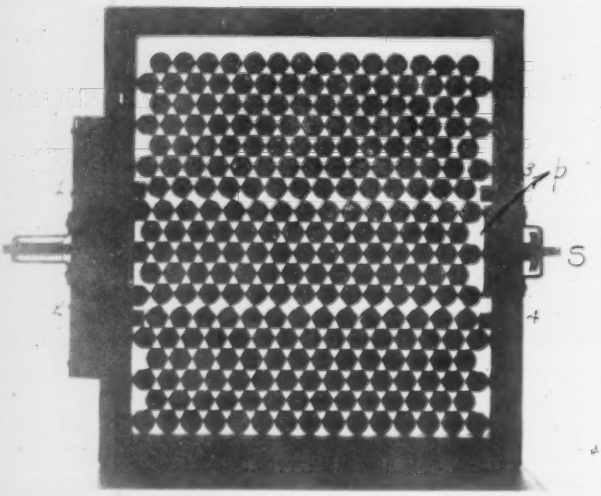


Fig. 24 (b). The five rows of balls have started to shear past the others.

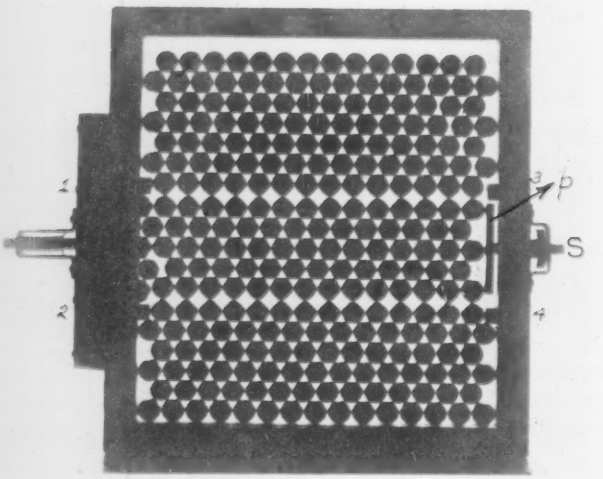


Fig. 24 (c). At the surface of slip the particles have in this set-up arrived at their largest spacings between the balls. By comparison with (a) it will be seen that the volume of the combination has increased. The balls are nearer the top of the frame in (c) than in (a).

Underlyin
In Hardnes

By S. R. WILLIAMS
Professor of Physics, Amherst College

PENETRATION

To answer the question, What penetrates what in the penetration method? one may say that it is the nosing of an aggregate of granulated granules into another aggregate of granulated granules. This process involves the changing of the distances and spacings between the atoms composing both the penetrator and the penetratee. The latter, however, suffers the greater change in distances and spacings between its atoms. This change in the spacings between the particles of the medium penetrated may in a crude way be illustrated by a model of a punch. Let the steel balls shown in Fig. 24, (a), (b), and (c), represent the atoms in a cross-section of a thin sheet of steel. The model consists of 261 steel balls, $\frac{3}{16}$" in diameter, placed in a wooden frame between two glass plates. Fig. 24 (a) shows the balls in a normal piling and undisturbed, while (b) and (c) show successive positions of the penetrator, *p*, as it is driven through the sheet. The penetrator drives ahead of itself those particles immediately in front of it and finally sets a cylinder of the particles to sliding (shearing) past the others. As it does so, it may be seen that the spacings between the balls are changed. The model is used here to show how a punch works. The four blocks, 1, 2, 3, and 4, shown at the ends of the rows of balls, adjoining the five moving rows, serve as the edges of the holes in the jaws of the punch. For illustrating the behavior of the particles composing the medium on which the penetration method of measuring hardness is used, these blocks will be removed. It may also be surmised that the symmetrical arrangement of the component parts of each atom is likewise disturbed in this process.

In dealing with these inter- and intra-atomic forces, let us see just how they come into play when the penetrator pushes into the penetratee. It has always seemed that the illustration of a snowplow pushing the snow away in front of it was in many ways similar to the penetration method produced by the wedge, cone or ball indenter. These remarks apply both to the penetration and scratch methods, for the scratch method is a penetration method.

For instance, how hard is a snow drift? The answer lies at hand: the resistance which it offers to the penetration of a snow plow. On what does this desistance depend? Upon four factors (see Fig. 25):

1. In the first place it will be some function of the angle ϕ formed by the two wings of the snow plow.

2. As the point goes into the snow, the crystal particles must be torn apart. The harder it is to pull the crystal particles apart, the greater will be the resistance to penetration of the snow plow.

3. The movement of the snow plow forward into the snow pushes crystal particles of the snow over one another. This gliding movement offers a frictional resistance to penetration which may correctly be called the internal friction of the material.

4. Finally, the snow will slide over the surfaces of the wings of the snow plow. If the surfaces are rusty

Conditions Measurements

Fourth instalment of
"Hardness and Hardness Measurements."
See page 1, Jan. 1937 issue.

or rough it will not slide easily, and thus another factor is brought into play to increase the resistance to penetration. A rusty plow for turning over soil also illustrates this fourth factor.

One may put these various factors into a symbolic equation, which could become an actual equation did we but know all the factors involved. Thus the resistance to penetration

$$R = f_1(\phi) + f_2(m_1 m_2 d^2) + f_3(\mu_1 p) + f_4(\mu_2 p)$$

where the subscripts of the fs correspond to the numbers attached to the factors on which R depends (see Fig. 25).

It will be seen that the first and last factors on which the hardness R depends are really properties of the penetrator and not of the penetratee. It is the hardness of the latter in which we are interested. The scratch method, the steel ball and cone indenters, used in measuring hardness, have these same factors involved.

To a physicist it always has seemed unfortunate to try to measure a property of a substance which becomes so hopelessly involved with the physical properties of the measuring tool. It seems as though emphasis was not being laid in the proper place to go on trying to improve a method which continues to have these inherent difficulties. Just to show the predicament in which a measurement-minded worker finds himself, one needs only to allow the same snow plow to stand around a few days and rust, when it will be found that the snow drift has increased its hardness!

PENETRATION BY A SHEARING OR BY A PLASTIC DEFORMATION

As an analogous experiment, a test plate was used under a steel ball indenter, first when the surface of the test plate was clean and dry, and again when oil covered the surface. Some materials increased their hardness, by as much as 4%, when oil covered their surface. No one imagines for a moment that the oil changed the hardness of the test plate. It was a difference due to the fourth factor in the above equation. Oiling the surface allowed the metal in the test plate to flow plastically under the steel ball without breaking. Whereas, if the surfaces of the ball and of the test plate are clean and dry, these surfaces stick to each other and cause the particles of the test plate to tear apart. Under these conditions, there is less elastic comeback on release of load than there is when the surface is not broken under the oil lubrication. An outstanding example of this is shown in soft rubber. The comeback after release of load makes rubber appear to be almost infinitely hard, which, of course, we know is not true.

It all amounts to saying that in all of the penetration methods—scratch or otherwise—the hardness as measured is going to depend upon whether the indentation is a plastic or brittle deformation.

The Indian, by a trial and error method, understood this centuries ago when, by means of a bone tool, he could chip the flint stone into an arrow head. He knew

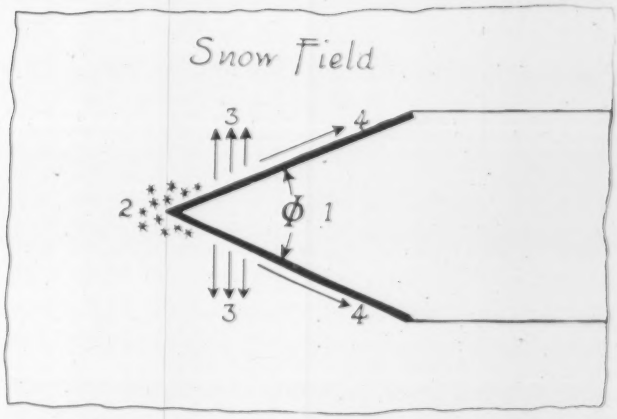


Fig. 25. As the point of the plow pushes into the snow drift the crystals are pulled apart. This offers resistance to penetration. The sliding of the snow crystals over each other and over the surface of the plow offers frictional resistance.

that he could disrupt the stone by a shearing stress, but could never fashion the stone plastically with a soft tool of bone.

It would seem that there has not been enough of a distinction made between hardness as measured plastically and that measured against a shearing strain. It is well known that in Moh's scale of hardness, it is easy for a beginner to make a soft stone scratch a harder one. It is a repetition of the Indian scratching a harder substance with a softer one. He shears off a portion of the harder substance by means of a softer tool.

If, in the equation for R (the resistance to penetration), one could eliminate factors 1 and 4 in measuring hardness, it is interesting to note that the factors left are those involved in the elasticity of stretch at the yield point. Factor 2 deals with the tearing apart of the particles which constitute the substance examined. Factor 3 depends upon the way in which these particles slip over one another as they move, *i.e.*, the internal friction between the particles constituting the material under test. Both 2 and 3 are inherent in the material tested. These two factors are just those which come into play when a body, subjected to a pull, reaches the elastic limit and the yield point is attained. In other words, could such a test be employed in practice, the yield point or the tensile strength would come more nearly to being a measure of hardness as now understood than any other property of matter. This is supported in a striking manner by the relations between Brinell numbers and the tensile strengths of carbon and alloy steels. The values from

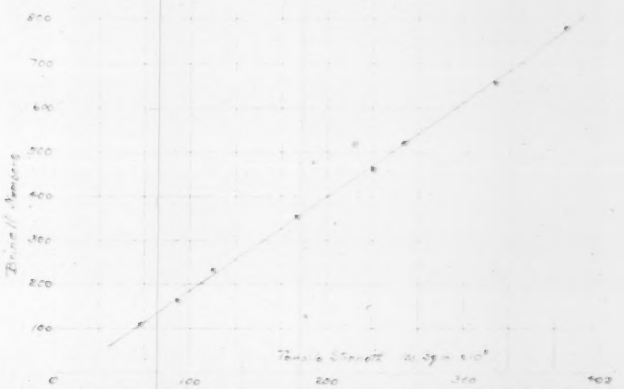


Fig. 26. Relation between hardness and tensile strength.

which Fig. 26 were derived are to be found in an informative pamphlet issued by the Heppenstall Co. on "Effects of Alloying Elements and Physical Properties of Steel in Forged Sections." Such a property is inherent in the substance to be studied and not in the instruments of measurements. In arriving at this point of view, one must not forget that in doing so, the conclusion has been reached by assuming at the start that hardness is measured by resistance to penetration.

EXCELLENCE OF PRESENT-DAY METHODS FOR MEASURING SUITABILITY OF MATERIAL

Although the author thus appears critical of indentation methods as a means of measuring what we call hardness, no one is more aware than he of the wide use and adaptability of our present-day hardness testers. For manufacturers, hardness tests offer a quick method for judging the suitability of materials for a certain use or for maintaining certain standards in the materials adopted.

The resistance to penetration rests upon the difficulty of pushing the granules, composing a body, to one side and getting them out of the way of the penetrator. Hardness seems to rest upon the inter atomic and inter molecular forces which hold these particles together in a solid. So far as we know, these are common forces and the overcoming of them is a measure of hardness. Such considerations seem to make hardness cut across materials composing solids and rest for the greater part upon the means whereby the forces holding these common granules together can be varied.

It seems, therefore, that a basic study might be launched in which those physical properties which depend upon these same factors might be related to hardness. It is conceivable that out of such a study might come methods for arriving at values of hardness quite as simple as the present, and bearing more directly upon hardness than does the penetration method.

The penetration and scratch methods include the majority of hardness testers on the market which employ mechanical procedure. Hardness testers using the rebound principle depend upon the elastic properties of the body tested as a measure of its hardness. The two frictional forces given in the equation for R would be negligible in this latter method. It may be seen also why the rebound principle may give hardness numbers which correlate satisfactorily with other methods. Elastic properties depend upon the interatomic forces, adhesion and cohesion, which correspond to the second factor in the above equation. Any method of hardness testing is somewhere dependent upon the elastic properties of the body tested. It is this factor, doubtless, which makes correlation possible. The rebound method depends only on the transient deformations for its readings, while the scratch and indentation methods depend on permanent deformations.

In the Brinell hardness testing machine the point of the penetrator is a steel ball. Such a point ought to make the third term in the equation important while a tester like the Vickers might enhance the fourth term. The shape of the point of the penetrator will largely determine the force necessary to produce a given penetration. This means that in using most of our present methods for hardness-testing, the hardness of materials will be a function of the shape of the nose of the penetrator. Hardness should be a property of the body penetrated and not of the penetrator.

HONDA'S THEORY OF HARDNESS

According to Honda[1,2] "Hardness is measured by the intensity of the maximum pressure applied to a surface which just produces yielding and admits of the penetration of the body exerting the pressure." By this definition, Honda seems to say that the elastic yield point is the measure of hardness. With this definition in mind, Honda proceeds to expound a mechanical theory of the hardness of metals. It is assumed that his theory may be applied to other substances than metals, for hardness is a physical property common to all solids.

Honda says: "It is first of all necessary to distinguish the hardness due to the molecular attractive force from that due to the crystalline structure of the metals. For example, a solid solution is homogeneous; for such a substance, the hardness must depend solely upon the magnitude of the molecular force, and no other cause can be sought for. A substance having a stronger molecular attractive force must be harder than that having a weaker molecular force. In this case, therefore, Tammann's theory[3] of the hardness of solid solution is quite correct. If two metals are able to mix with each other for all proportions, then the hardness of the alloy generally exceeds that of either of its components and this hardness has a maximum in an alloy containing an equal atomic quantity of the components. For, the fact of the miscibility of two metals indicates that the molecular attractive force acting between the molecules of different metals is stronger than that in the case of the same metal; and therefore, if the two metals form an alloy, the mean molecular force must be greater than that of the respective metals."

"Next let us consider the hardness due to the crystalline structure. Suppose a metal to consist of an immense number of acicular or needle shaped crystals, which are imbedded in a homogeneous component or in a solid solution and have their lengths all parallel to each other. The metal then very strongly resists the tension acting in the direction of the needle crystals. For, as is well known, a wire can resist a strong tension, though it bends by a small force acting perpendicularly to its length, and this analogy is quite sufficient to account for the great resistance to the applied force above mentioned. If the direction of the axes of needle shaped crystals be uniformly distributed in all directions, then the metal must resist the tension or compression acting in any direction very strongly. For, a compression acting in a direction will result in stretching certain fractions of the whole needle-crystals and therefore produce tension in these crystals. A good illustration will be found in the case of the wheels of a bicycle, in which a certain number of spokes radiate from a common center toward the circumference. It is well known that although the spokes are very thin, the wheel resists a great tension or compression acting in any direction in the plane of the wheel. Hence, if a metal contains five acicular or needle shaped crystals and their axes are uniformly distributed in all directions, it can resist a large force acting on it in any direction, that is, the metal is hard. By this theory a metal is harder, as its structure is finer and the crystals are in a highly stretched state. A fine net-work structure also produces in a like manner a high degree of hardness."

"The above theory may be briefly expressed in the

[1] K. Honda, On a Mechanical Theory of the Hardness of Metals, *Science Reports, Tohoku Imperial University*, Vol. 6, 1917, pages 95-99.
[2] K. Honda, Sur la Théorie de la Dureté des Métaux, Communication présentée au cinquième Congrès de Chimie Industrielle, 4-11 Octobre, 1925. 1-7-page report, Extrait des Comptes Rendus du Cinquième Congrès de Chimie Industrielle, Chimie et Industrie, 49, Rue des Mathurins, Paris.
[3] G. Tammann, Lehrbuch der Metallographie, Leopold Voss, Leipzig, 1914, page 332.

owing words: For a given substance having a definite ecular force, its hardness increases with the fineness the strained state of structure; and for the same cture and the same degree of strain, the hardness of bstance increases with the strength of its molecular e. This theory, though it is very simple, explains ny observed facts quite satisfactorily. Thus the hardng of steels by quenching is the consequence of the oduction of fine martensitic or acicular crystals cemented together by solid solution. These fine crystals ill probably be found in a highly strained state by apid cooling, like the tightened spokes of a bicycle wheel, and, therefore, the quenching produces the hardness of the metal. The annealing of the quenched specimen will cause a union of these fine crystals, as well as the relaxation of the specimen from the strain, and therefore the hardness will diminish by annealing."

"The hardening by cold working or by overstraining is also explained in a similar way. The process is analogous to that of tightening the spokes of the wheels of a bicycle to assure its solidness. Cold working or overstraining is to put these fine crystals, cemented together by solid solution, in a highly stretched state. This state corresponds obviously to the hard state of the substance. In this respect, my theory coincides with the interstrain theory; the latter theory, however, does not explain why the interstrain causes a greater hardness of the substance, but in my theory, the hardness is explained by a well known mechanical property of the material. By annealing a specimen which underwent a cold working, the strained state of the minute crystals is lessened and therefore the hardness decreases."

This theory of Honda's is a suggestive one and needs further study and consideration. For instance, Griffith[4] in a study of glass fibers reported a large increase in the tensile strength of the fibers as the diameter was decreased. Fibers with a diameter of 0.040 inches showed a tensile strength of 25000 lbs. in.$^{-2}$, while for fibers 0.00012 in. in diameter he found a tensile strength of 492,000 lbs. in.$^{-2}$. Glass is an amorphous substance. On the basis of Honda's theory, how is the intermolecular force increased? Does the drawing of the glass into fine fibers produce such surface tensions as to produce this increase in intermolecular forces?

HOWE'S POINT OF VIEW

While his book is older than some of the theories of hardness, Howe's statement[5] may not be out of place at this point:

"Hardening is usually due to martensitization, that is, to enabling the transformation to proceed to but not past the martensite stage, either (1) by cooling carbon steels rapidly from the austenite state, or (2) by the presence of such an intermediate proportion of the obstructing elements, carbon, nickel and manganese, as to cause the transformation to reach only this stage, even in slow cooling; or (3) by bringing it to this stage by subcooling cold austentitic steel, *e.g.*, in liquid air; or (4) by overstraining austentitic steels by cold deformation, so as to stimulate the overdue change from the austentitic to the martensitic state. In addition to these four martenizing methods of hardening there are two others, which we may call (5) and (6). (5) is the hardening of austentitic steels by a regulated reheating, which gives mobility enough to allow the transformation to go as far as the hard intermediate state, but not enough to let it reach the final alpha state. This hardening does not always cause martenization. (6) is the hardening of the malleable metals and alloys in general, gamma and alpha iron included, by plastic deformation. There is neither evidence or reason for believing that this usually acts through martensitization, except in the case of gamma iron."

SAUVEUR'S THEORY

Sauveur also discusses[6] various theories of why steel may at one time be soft and at another hard.

TIEMANN'S REVIEW

After discussing several theories of hardening, such as Osmond's theory, the "carbon theory of hardening" and the "carbo-allotropic theory," Tiemann[7] proceeds to classify the various theories under four distinct heads:

(1) "Carbon theories of hardening."
(2) "Stress theories of hardening."
(3) "Plastic deformation" and
(4) "Amorphous cement theory."

Osmond's theory is sometimes known as the beta iron theory. Metallurgists are fairly well agreed that no such form as beta iron exists, *i.e.*, not as a distinct allotropic form in which a change in atomic arrangement occurs. This would rule Osmond's theory out of consideration. At 903° C. pure iron exhibits discontinuities which are now known to correspond to atomic rearrangements or changes in space lattice. Alpha iron is a modification stable below 903° C. and has a body-centered cubic lattice, while gamma iron is stable above 903° C. and has a face-centered cubic lattice. See Figs. 5 and 6.

The short review of hardness theories by Tiemann leaves one with the feeling that the various theories of hardness overlap widely and are more or less confusing. This is natural, no doubt, because of our ignorance concerning the property of hardness.

SLIP THEORY OF HARDNESS

The theory which seems most consistent with itself and has more experimental evidence presented in its substantiation than others is the one advanced by Jeffries and Archer.[8] They have called it "The Slip Interference Theory of the Hardness of Metals." (Of course the physicist looks at hardness as a general property of solids, whether metals or non-metals.) These metallurgists start out by defining hardness as "resistance to permanent deformation." This is different from the definition that hardness is "resistance to penetration." The latter will allow for the forces of friction between the atoms of the body tested and those of the penetrator, if penetration methods are to be employed in hardness testing.

Permanent deformations may be characterized by the point of yield in the stress-strain curve, as shown in Fig. 27. To quote Jeffries and Archer, "Metals owe their resistance to deformation to the forces between the atoms. These forces are both attractive and repulsive. Repulsive forces are manifested by the resistance of metals to hydrostatic pressure by which the atoms are forced closer together in all directions. Under direct tension the distances between atoms are increased in the direction of the load and decreased at right angles, that

[4] A. A. Griffith. The Phenomena of Rupture and Flow in Solids. *Philosophical Transactions of the Royal Society of London, (A)*, Vol. 221, 1920, pages 163-198.

[5] H. M. Howe. Metallography of Steel and Cast Iron. McGraw-Hill Book Co., N. Y., 1906, page 176.

[6] A. Sauveur. Metallography and Heat Treatment of Iron and Steel. McGraw-Hill Book Co., N. Y., 1926, page 308.

[7] H. P. Tiemann. Iron and Steel, 3d Edition. McGraw-Hill Book Co., N. Y., 1933, pages 322-328.

[8] Z. Jeffries and R. S. Archer. The Slip Interference Theory of the Hardening of Metals. *Chemical and Metallurgical Engineering*, Vol. 28, 1923, pages 1057-1067. See also Chapters 11 and 12 of their book, The Science of Metals, McGraw-Hill Book Co., N. Y., 1924.

is, in the direction of the secondary compressive stresses. There is no condition of loading corresponding to a negative hydrostatic pressure, under which the interatomic distances would be increased in all directions." [The nearest approach to this is in the change in volume of a ferro-magnetic body when magnetized.] "Any permanent deformation of a metal involves changes in the relative positions of some of the atoms, and therefore, the breaking, temporarily at least, of some interatomic 'bonds'. The rupture of any material, whether with or without permanent deformation, also involves the breaking of interatomic and intermolecular bonds. The greatest possible resistance that a material can offer to deformation or rupture is the summation of all the interatomic bonds on a plane through the specimens normal to the stress, a summation which may, for convenience, be termed the 'absolute cohesion' of the material. Actually, such a summation of forces is never realized, because rupture always takes place by degrees, and the breaking of atomic or molecular bonds is not simultaneous. The tensile strength of a material merely represents the maximum number of atomic bonds that came into play simultaneously during the test. Absolute cohesions of metals are far in excess of the values obtained for tensile strength."

"Metals are crystalline and are built up of atoms arranged in definite and repeating patterns. The regularity of atomic arrangement gives rise to certain planes of weakness, or low resistance to shearing stress. When an external load produces a shearing stress on some plane, which exceeds the resistance of the crystal to shear on that particular plane, fracture of the crystal takes place."

(In this connection it will be found interesting to read A. F. Joffe's book, "The Physics of Crystals," 1st Edn. 1928, and in particular Chapters 3 and 4.) Resuming quotation from Jeffries and Archer:

"The fragments formed may or may not adhere to each other. If they do not, the failure of the crystal is complete, and it is said to be brittle. The plane of weakness is known as a 'cleavage plane.' More generally in the useful metals, the crystal fragments adhere and merely glide or slip over each other. The result of such slip, repeated on many planes, is a measurable permanent deformation. The crystal is ductile, and the planes of weakness are called 'slip planes'."

"The first appreciable formation of slip planes marks the beginning of plastic deformation and, therefore, the passing of the elastic limit. The resistance to permanent deformation, which is a general measure of hardness and strength, represents resistance to the beginning and propagation of slip. Anything that serves to hinder slip is a source of strength and hardness. *The hardening and strengthening of metals by any known methods may be considered as due principally to interference with slip.*"

One other theory is suggestive, known as Hertz's theory of hardness. In a report of the Hardness Tests Research Committee of the Institution of Mechanical Engineers for 1929, a brief summary of it is given:

"*Hertzian Hardness.*—The Hertz theory of hardness may be exemplified by considering two rounded bodies which just touch one another. When these are pressed together, the original point of contact increases to a definite area, and when both bodies are spherical or one is a plane and the other spherical, the contact area is a circle. From purely elastic considerations Hertz derived expressions for the stresses and strains at all points in the two bodies, and hence for a known pressure and from measurements of the contact circle, the maximum shear stress in the materials can be obtained. Various investigators have shown that the Hertz analysis is in approximate agreement with experimental measurements, when the elastic limits of the materials are not greatly exceeded. Accordingly, the mean normal pressure over the contact area at the first deviation from elasticity can be taken as a rational measure of the hardness when two metals are in contact, and is definitely related to the elastic constants and elastic limits of the materials. The use of the Hertz theory in hardness measurements has been discussed in detail by Innes,[10] and Esnault-Pelterie[11] has used the method for tests on hardened steel balls in contact. Unfortunately, the elastic limit of most engineering materials is not very definite, and the measurement of the small contact area is difficult, so that the method cannot be used as a general test, despite its rational basis."

Hertz's theory has also had an interesting confirmation in some work done by Föppl[12] who worked with crossed cylinders. Other theories will be found in the references given in an appendix. *To be continued.*

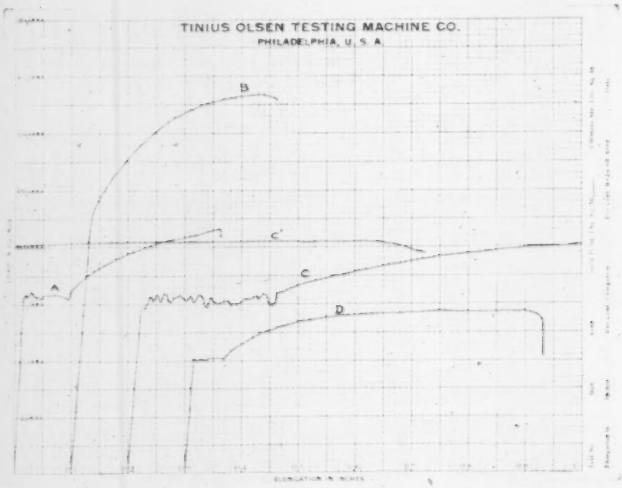


Fig. 27 illustrates curves of four specimens drawn on one chart with 10:1 magnification throughout. Curves A, C, and D show clearly the action of the specimen around the yield point. These curves are not affected by any slippage in the grips, as they are produced through the use of clamps on the specimen at definite gage lengths. Specimen "C" had a long gage length, and having considerable elongation, passed beyond the limit of the chart and continued on the next revolution of the autographic cylinder in the line C', which is a continuation of the Curve "C." The cylinder will make several revolutions, if necessary, and the curve may be continued around the cylinder as many times as may be necessary or desirable. Curve "B" indicates the characteristics of a malleable cast iron specimen which does not have a sharply defined yield point. This curve shows general characteristics of the complete test, but the yield strength is better indicated by the high magnification recorder as illustrated by other curves as described below.

Curves A, C, and D show the typical "upper yield point" (or highest point of yield) and the lower yield point (or lowest point of yield) besides giving the "yield range," which information is of great value to the research or test engineer. The "yield range" in a tension test is the amount of deformation that the material undergoes during the yielding period.

Courtesy of Tinius Olsen Testing Machine Co.

[10] H. Hertz, Über die Berührung fester elastischer Körper und über die Härte. Verhandlungen des Vereins zur Beförderung des Gewerbfleisses, 1882, pages 449-463.

[11] Innes, Measurement of high Degrees of Hardness, *Proceedings Institution of Mechanical Engineers*, 1920, pages 915-920.

[12] Esnault-Pelterie, Apparatus for Measurement of Hertzian Hardness, *The Engineer*, Vol. 146, 1928, pages 180-195.

[12] A. Föppl, Ueber die Mechanische Härte der Metalle, besonders des Stahls. *Wiedemann's Annalen*, Vol. 63, 1897, pages 103-108.

athode-ray Oscillograph Applications

Second part of "The Cathode-ray Oscillograph and Its Applications" being published serially in *Instruments*. This series began in July 1935 issue.

By RALPH R. BATCHER

Radio engineer; cathode-ray and electronic application specialist, Hollis, L. I., N. Y.

AUTOMOTIVE TESTS

(Concluded)

MISCELLANEOUS TESTS ON AUTOMOTIVE EQUIPMENT[10-15]

Other automotive design problems that are especially suited to cathode ray analysis are: studies of body and chassis vibrations, crankshaft balance, stethoscope analysis of noises, pressures and stresses in springs and shock

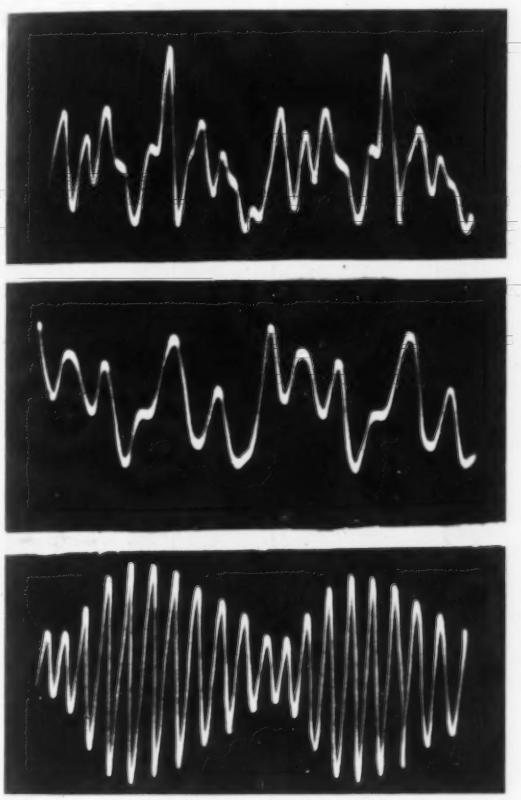


Fig. 7

Fig. 8

absorbers, vertical acceleration (bouncing) under different roadbed conditions, tire pressures and tire and spring shapes. Conversely, some such device can be attached to the axle to give an indication of the blow to the pavement caused by vehicle types when making life studies of paving methods.

Detailed suggestions regarding these applications will not be given here. Reference to the symposium by several authors, on recent trends in automotive comfort engineering, in the October, 1936, *Instruments*, is suggested. It may be pointed out that inter-related vibration and springing effects can be relatively compared in many cases by utilizing deflection in two directions, without necessarily bringing in a time factor, except that which indicates the "phase" between vibrations in two planes. Acceleration instruments have been described in the June, 1936, article.

An altogether different kind of investigation, for which cathode ray tubes are useful, is found in the field of acoustics. An example is shown in Fig. 7 where the tones of three types of automobile horns are analyzed and compared. These oscillograms, from the General Radio Co., were obtained using the test set up shown in Fig. 8. To obtain each of these oscillograms, a linear time base was set at a frequency equal to one half of the fundamental tone, so that each figure represents two complete cycles.

MISCELLANEOUS INDUSTRIAL APPLICATIONS

TORSIONAL DISTORTION IN SHAFTS

In the preliminary design of any type of prime mover, and in many other fields, the measurement of torsional stresses and momentary changes in the angular relation between separated portions of the same mechanism becomes an important problem. Representative of these studies, the measurement of strains in a long shaft will be considered, such strains being due to either load or power variations. Several methods are possible, the particular type best suited for any test depending upon the ease with which the accessories can be applied to the actual shaft without disturbing it or the conditions under which it operates.

If the shaft is not so tiny that anything heavier than a chalk mark would introduce inertial effects, and if its ends are both exposed, small synchronous alternators can be directly coupled to them, permitting direct comparison of the oscillograms of their generated potentials by the phase rotation method. In certain cases it may be desirable to connect the alternators in series, whereby (assuming a balanced output from each) the potentials are out of phase and neutralize each other when no shaft distortion is present. If torsional strains cause the shaft to twist, the alternators are no longer of opposing phases and a potential results.

Another method utilizes one or more small auxiliary flywheels which would rotate freely on the shaft at the test position (or positions) except for the fact that they are coupled to the shaft by driving arms, having the general appearance of lathe dogs. A piezoelectric coupling unit of the pressure type is incorporated in this driving arm, and is connected through amplifiers to the deflection system of the cathode ray tube. Relative changes between the speed of the flywheel (assumed to be constant) and the shaft (which is assumed to have momentary variations in speed) show up as electrical

[10] Sieber, Vibrograph for Acceleration Studies, *Archiv. Eng. Technical Mission*, Nov. 1931, page T39.

[11] Webster, Piezoelectric Gage and Amplifier, *Journal of the Franklin Institute*, Vol. 211, 1931, pages 607-615.

[12] Serrus, Piezoelectric Observations on Engine Knock, *Comptes Rendus*, Vol. 197, 1933, pages 1296-1298.

[13] Field, Study of Mechanical Vibrations, *Canadian Journal of Research*, Vol. 8, 1933, pages 563-.

[14] Ervin, Piezoelectric Gage for Ballistic Studies, *Journal of the Franklin Institute*, Vol. 213, 1932, pages 503-513.

[15] Watanabe, A Study of Impact Test by Cathode Ray Oscillograph, *Scientific Papers of Institute of Physical & Chemical Research*, Vol. 12, 1929, pages 99-112.

[1] Rolf, Electrical Indication and Recording of Torque, *Elektrotechnische Zeitschrift*, Vol. 54, 1933, pages 1160-1163.

pressures and consequent changes in the deflection amplitude. A single unit connected at one point along the shaft will indicate the momentary acceleration, and two units properly synchronized will indicate torsional distortion.

Such devices will have to be calibrated experimentally in terms of pressure or displacement.

Under test conditions where torsional stresses are exactly repeated during successive revolutions, a more simple arrangement can be applied that permits a point by point check over a cycle. The items attached to the shaft at the two test positions can usually be made small enough to permit their installation on existing machines. They consist of electrical contacts in the form of short

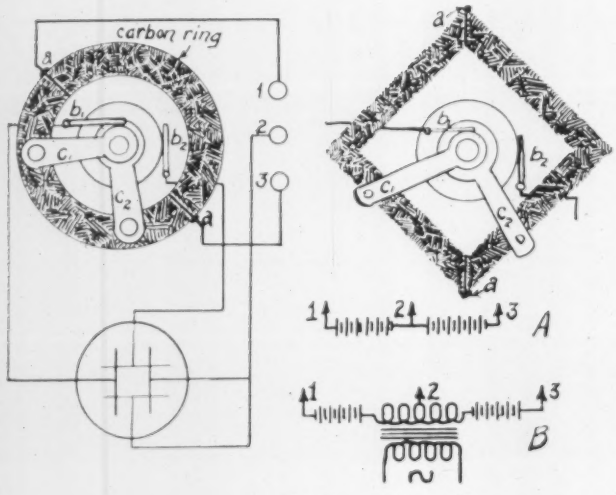


Fig. 1

segments of some conductive material, affixed to the periphery of the shaft, and in electrical contact with it. Two brushes associated with these segments are mounted so that the two points of contact are in a plane passing through the axis of the shaft. Current applied to one of these brushes enters the shaft during a particular interval of each revolution and returns to the external circuit through the other brush. The pulses thereby resulting are amplified through a suitable amplifier and their duration is measureable on the oscillograph. The frequency of the pulses depends of course upon the speed of the shaft, and is of no great importance. The length of each pulse, however, depends upon whether the point of contact at one position has shifted angularly by reason of shaft distortion.

If such a lag is constant over the whole revolution a single measurement will suffice, and any method of measuring pulse duration can be used. If the distortion varies throughout a revolution the brush holders must be so mounted that they can be rotated slowly around the shaft in synchronism with each other, so as to maintain synchronism in the contacting interval with no distortion. Under test loads, however, at certain positions during such revolution of the brushes, the pulse duration will appear to increase or decrease by reason of the torsional displacements. The horizontal deflection can be either a linear time scale or a circular time scale varying linearly with the rotation of the pair of brushes.

POSITION INDICATORS[2]

In many fields of investigation the problem of transmitting to a distant point an indication of the instantaneous position of a certain mechanism has been encountered. In this service a cathode-ray tube gives an instantaneous, inertialess indication. The method may be extended for service as a synchronous time base when the spot follows a circular or irregularly shaped path in accordance with the movements of a master. The simple arrangements, for reproducing a linear movement, or for converting a rotary movement into a linear one, have been discussed in the May, 1936, instalment.

If a circular rheostat is so connected that it can be rotated by the master mechanism a linear deflection results. In order to make the spot follow a circular path the connections indicated in Fig. 1 can be applied. The resistance element can be made of two semi-circular strips, with the ends joined at a-a, and arranged so that the sliders can rotate continuously. The two sliding arms, c_1 and c_2, are insulated from each other and are located 90° apart.

If a d-c. potential is applied to the terminals 1, 2, 3, as shown by battery connection arrangement *A*, the spot will describe a trace that is essentially a square, each time that the arms complete one revolution. If an a-c. is applied to the same points a radial line of light will

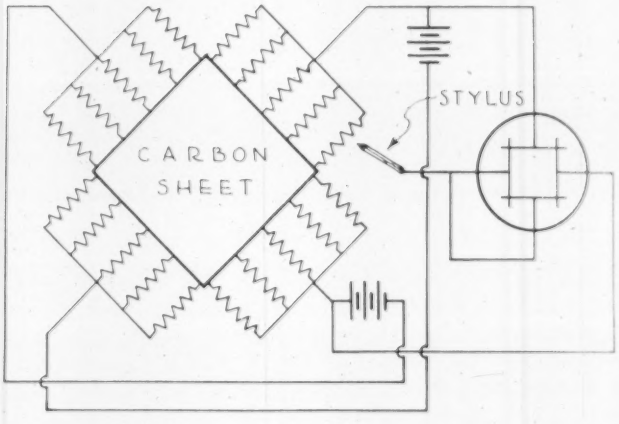


Fig. 2

rotate following up the motion of the rheostat arms. The motion in either of these cases does not exactly duplicate the master, however, but follows the relation:

$$\varphi = \cot^{-1}[1 - (90 - \theta)]$$

where θ and φ are the angular displacements of the master and the indicator respectively. The envelope of the trace is a square. If the rheostat is made up of four mitred carbon rods, also shown in Fig. 1, this discrepancy can be eliminated and a calibration curve is therefore unnecessary. The four sections of the resistance element should have equal values.

Depending upon whether the applied deflection potentials are from an a-c. or a d-c. source, the screen indication can be either a line or a spot. In the former case, however, the indication is ambiguous as it points in two directions. By connecting polarizing batteries in series with the a-c. supply source, as shown in the *B* connection arrangement, the indication can be made unilateral.

In another application, the utilization of small two- and three-phase Autosyn alternators as a means of controlling the deflection of cathode-rays will be described.

The preceding remote indicator arrangements can be extended to a two-dimensional indicator, such as a writing or mapping device, by substituting a thin square carbon sheet for the rectangular rheostat. As shown in Fig. 2, a metal stylus is used to replace the rotating

[2]Watson-Watt. The Cathode-ray Oscillograph in Radio Research. His Majesty's Stationery Office.

s of the rheostat. Two sets of batteries, each having otential sufficient to deflect the spot across the screen, connected to the edges of this carbon plate through mber of resistors. These resistors should each have sistance approximately the same as the edge-to-edge stance of the plate. The edges of this plate should be coppered.

The spot on the screen will follow the movements of stylus on the carbon plate, whether those movements linear or irregular, producing effects somewhat like ose of the Telautograph. More than one receiving tube can be applied to any of the devices described above.

An application of the Telautograph principle has been demonstrated[1] using two linear potentiometers with their sliders mechanically linked to the writing pen. One of the greatest advantages of these systems is the ability to communicate instantly over a distance, quietly and without leaving permanent records, so that secrecy is assured.

Another application of a cathode ray-tube as a position indicator has been devised by Watson-Watt and Bainbridge-Hall.[3] A special tube is used, having an anode divided into sectors, each supplied with a separate lead. If the jet is not deflected (due to any manner of deflection potentials applied) it passes through the central opening without striking any of the sectors. If, however, it is diverted, striking one or more sectors, the charge collecting thereon is applied to amplifiers. A separate amplifier is used for each sector, and their outputs actuate relays whereby motors operate levers or gears so arranged as to tilt the tube enough to cause the jet again to strike the center of the screen. For example, assume that the earth's field is utilized to cause the original deflection (in an aircraft orientation device), causing the jet to strike a particular segment. A particular motor starts up and the operating mechanism counteracts this deflection by moving the tube until the spot is again centered.

British patent 365,073 shows a cathode-ray tube freely suspended as a pendulum. The relative angular displacement of the jet from the axis of the tube, as for instance due to the earth's field, may be used to indicate the inclination of this field. This application, too, was particularly developed for aircraft use.

RADIO DIRECTION FINDERS[5-12]

For both marine and aviation applications, a direct reading radio direction finder has the advantage that it eliminates manual operations. The rotation of loops while observing relative signal intensities is avoided. Considerable work has been reported on this system by several research organizations in Great Britain and elsewhere.

Early experimenters tried large loops connected to the deflection system without amplification, but the results were reported unsatisfactory except for powerful signals.

In another arrangement two similar loops are permanently mounted on the craft at right angles to each other. Each loop is connected through matched amplifiers to the two sets of deflection plates in a cathode-ray tube. See Fig. 3. The tuning of both amplifiers is accomplished with a single control. The diagram appearing on the

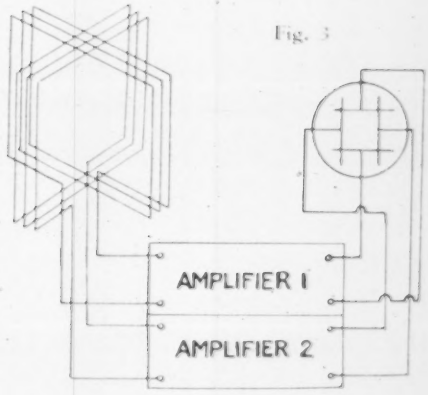


Fig. 3

screen is the resultant of the signal intensities and appears as a line which may be interpreted as direction. Or if desired the cardinal points of the compass are painted on the screen direct. The deflection may take place at either a radio frequency or an audio frequency as far as theory is concerned. The amplifiers, however, must be identical to prevent both variations in the relative gain, and must be even more stable as to changes in phase.

LIGHT MODULATOR

A cathode-ray tube can be adapted in several ways to serve as a light-wave valve. The normal method is to deflect the jet back and forth across the screen, which is made opaque except for a small slit parallel with the line of deflection. In some cases it is desirable to use a line of light instead of a spot, by the application of an ultrasonic frequency to the alternate set of deflection plates.

In tubes equipped with a modulation grid the problem is simpler because the light intensity can be controlled directly by varying the bias voltage.

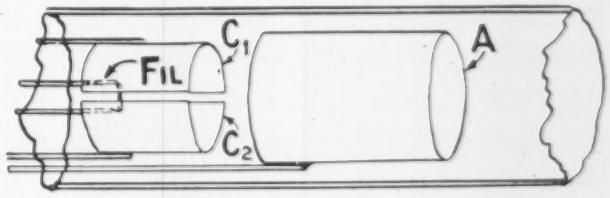


Fig. 4

Other methods, however, are possible. In tubes using a Wehnelt cylinder as a focusing agent, a fine jet can be directed at the orifice in the anode. A small magnetic control field, applied between the anode and cathode, will divert this jet so that it no longer strikes the opening in the anode.

A special tube constructed for the author utilized a split Wehnelt focus cylinder, made up of two semi-cylindrical plates with separate leads through the stem. See Fig. 4. If the same bias potential was placed on both halves, this cylinder focused the jet in usual way, but if the potential on one of the halves was altered slightly the direction of the jet was diverted to partially or completely miss the anode orifice. Potential variations from a microphone without amplification were sufficient to modulate the stream.

[1]DuMont, Telautograph, U. S. Patent No. 2,000,014.
[2]British Patent No. 366,986.
[3]Watson-Watt, The Cathode-ray Oscillograph in Radio Research. His Majesty's Stationery Office, London.
[4]Friis, Feldman, Sharpless, Determination of Direction of Arrival of Short Waves; *Proceedings Institute of Radio Engineers*, Vol. 22, 1934, pages 47-79.
[5]Friis, Oscillographic Observations on the Direction of Propagation, *Proceedings Institute of Radio Engineers*, Vol. 16, 1928, pages 658-665.
[6]Dean, Correlation of Directional Observations of Atmospherics with Weather, *Proceedings Institute of Radio Engineers*, Vol. 17, 1929, pages 1185-1191.
[7]Harper, Some Measurements on the Directional Distribution of Static, *Proceedings Institute of Radio Engineers*, Vol. 17, 1929, pages 1214-1223.
[8]Munro & Huxley, Observations with a Cathode-ray Direction Finder, *Journal Institute of Electrical Engineers*, Vol. 71, 1932, pages 488-496.
[9]Watt & Herd, Instantaneous Direct-reading Radiogoniometer, *Journal Institute of Electrical Engineers*, Vol. 64, 1926, pages 611-622.
[10]Strolenk, Cathode-ray Compass, *Electronics*, Vol. 9, Aug. 1936, pages 12-15 and 45.

SOUNDS, NOISES AND VIBRATIONS

The following selection of a few of the commoner applications of cathode-ray equipment to sounds, noises and vibrations is only designed to call attention to methods. It is an exemplary selection rather than an exhaustive compendium of scientific tests.

It can be said that the vigor with which such "intangible" entities as sounds have been studied has brought about improvements in many fields of art and industry, which may never have been brought about by the former cut-and-try methods. A certain Stradivarius violin, for example, may be hailed as a paragon of the violin maker's art, because the ears of musicians have judged it so for many years. If so, why? Apparently the old adage that "seeing is believing" still holds, for the last word in musical tone analysis is a visual record—an oscillogram. The study and improvement of musical instruments are but one example of oscillography co-operating with the arts. The equipment and methods for at least a preliminary investigation are simple, consisting only of a high-quality microphone and an amplifier to pick up the sounds and to convert them into deflection voltages.

The public is becoming more and more interested in the elimination of needless noises and vibrations and this field is destined to become an important branch of engineering. Vibration engineering is closely associated with acoustics; and in common with other specialties it borrows from the technique of many other fields—in this case the problems involve architectural, mechanical, electrical, physical and even psychological sciences.

ARCHITECTURAL ACOUSTICS

The problems here are mainly concerned with reverberation. This is measured by determining the decay time: for a given sound energy density to die away after the source is removed. In other words, it is a measurement of the decrement of the sound wave (Fig. 1). This had been done by judging the decay by ear and by stop watch. Another old method required the measurement of the sound energy level at definite intervals—a method of sampling. Obviously, a continuous record on an oscillogram is an advantage, since both time and amplitude can be accurately delineated and compared. Reverberation time differs with the pitch of the tone; standing waves are introduced by wall reflections, and a number of other factors complicate the tests, so that in many cases the oscillograph becomes not only an advantage but a necessity.

A common method is to use electrical means for both initiating the tone and picking up and amplifying it. When an oscillograph is used the decay period is delineated directly on the screen. In common with the measurement of other phenomena in other fields involving decrement the frequency of the linear time base can be set at, say, one-tenth of the driving tone frequency (assuming the latter is a fixed tone), whereupon portions of the train of waves, ten cycles apart, are superimposed so that the ratio of heights of cycles separated at that interval can be directly measured.

In case a heterogenous sound is used for the test in order to average the effects of reflection patterns, no distinguishing wave can be noticed which can be measured using the preceding method. In this case, the amplifier can be blocked at a definite rate so as to break up the received tone into groups of pulses, by the application of an alternating current of a suitable frequency and voltage to the grid bias circuit of one of the tubes.

[6] Christer, Measurement of Sound Absorption by an Oscillograph. *Journal Acoustical Society of America*, Vol. 1, 1930, pages 418-421.

MUSIC AND SPEECH

Knowledge of the peculiarities of musical tones—their production has been greatly augmented by efforts toward synthesizing well-known sounds, a particular utilization of oscillographic studies in wave form. Aside the oscillograph, no unusual equipment is required for such studies, other than a suitable microphone-amplifier. The method is becoming particularly important as an adjunct to training the singing voice. The main reason for using a visual delineation of voice waves is that the student cannot hear his own voice exactly as it is heard by others. Various adjustments of the oral cavities each produce different tone values. Such differences can be shown with sufficient exactitude by the instantaneous visual demonstration in front of the singer so that the pictures can be compared with standard or desired oscillograms.

Investigations of violins may be concerned with quality of strings, correct thickness and placement of the bridge and sound post,[7] the bow and its operation and many other factors. The correct technique of bowing may be simulated by automatic bowing devices if continuous tests are required instead of manual bowing which may vary enough to blur the results on the screen.*

Another application in the musical field is in the accurate tuning of musical instruments, in setting the strings in exact harmonic relation or, where two or three parallel strings are tuned to the same note, in getting each tuned to exact resonance with the others.

In the critical analysis of musical tones, a complete spectrum survey has been frequently utilized. While the equipment associated with such a test is rather elaborate, it can usually be assembled from apparatus available on the market. Each single tone under test is heterodyned with a locally generated frequency having a value so that a resultant (sum) frequency of, say, 20,000 cycles is obtained. This combined frequency can then be passed

[7] Curry, a Cathode-ray Oscillograph in Speech Analysis. *Journal Scientific Instruments*, Vol. 11, 1934, pages 162-164.

[8] Trendelenburg, On the Physics of Speech Sounds. *Journal Acoustical Society of America*, Vol. 7, 1935, pages 143-150.

[9] Wolf & Stephenson, Velocity of Sound. *Physical Review*, Vol. 2, 1913, page 506.

[10] Marrò, Voice Analysis. *Electrician*, Vol. 113, 1934, pages 252-253.

MacLean and Sivian, Direct-reading Audio-frequency Phase Meter. *Journal Acoustical Society of America*, Vol. 2, 1931, pages 439-455.

Uniform excitation is best achieved by the continuous action of an endless belt (many turns of one lacquered silk thread or silver wire, as used by Prof. Abbott, Purdue University) or of a laminated celluloid-and-rubber wheel (as used in the nickel-in-the-slot violin and piano player). It may also interest music-loving readers to learn that oscillography is gradually refuting the supposititious correlation between richness of tone and expensiveness of violin, and on the other hand confirming the correlation between tone values and virtuosity of performer. In other words, an inexpensive fiddle and a Guarneri, in identical mechanical emplacement and under identical mechanical excitation, may sound much alike (or unpleasantly); but a good violinist can make both sing sweetly. The inexpensive fiddle would then be a prodigious bargain, but others from the same production lot of the same manufacturer might be incapable of giving forth pleasant music whether played by a machine or by Menuhin. Oscillography *has* made it possible (and *may* cause manufacturers) to *grade* violins and other string-and-bow instruments, or to label each with a certificate reporting its laboratory characteristics in quantitative terms, the weighted average of these numbers then being the Figure of Merit (scientific—not workmanship, etc.) whereby the instrument falls into "Grade AAA" commanding a large premium or into "Grade D" taking a large discount. The characteristics which can truly *measured* include all which have been recognized as important by a host of workers from von Helmholtz half a century ago to Miller, Fletcher, and others today. Among these characteristics are:

Tone-center, or Centroid. The "center of gravity" of the acoustic spectrum. This is a quantitative measure of the position of a sound's tone quality on the voice scale. If relatively high, the tone is "metallic" and "rough"; if relatively low, the tone is "soft" and "mellow." In the case of a shrill or metallic tone, the partials (frequences not necessarily harmonics of the fundamental) are high-frequency and high-energy-level.

Tenth Balance. Expressed in terms of unbalance. Perfect balance means that all four strings have the same "response" (output in terms of energy). The sum of the deviations from the mean is the measure of unbalance.

Quality. Tone structure. Ideally, the complete spectrum; practically, the distribution and intensities of partials; numerically, Fletcher's ratio.

Editor *Instruments*

gh a 20,000-cycle band pass filter having extremely
characteristics, and amplified and measured.

ssuming a tone of 256 cycles is being analyzed, if a
onic of 512 cycles is present it would thus produce
ombination frequency of 20,256 cycles which would
pass through the filter. However, if the heterodyne
quency was changed to 19,488 cycles, this harmonic
would be passed for subsequent amplification and
asurement.

Therefore, by altering the heterodyne note over the
nge from zero to 20,000 cycles, all harmonics are
parately "exposed" to the recording apparatus. These
equency excursions of the local oscillator can be pro-
ded by a motor-driven beat-frequency oscillator of the
sual type. Its scale can be calibrated according to the
difference frequency—that is, the filter pass frequency
inus the frequency delivered at each setting.

This method utilizes a cathode-ray oscillograph to
show the complete spectrum. The linear time base must
be driven at the same speed as the frequency control
capacitor in the oscillator. A potentiometric arrangement
on the same shaft can be used because the speed is
relatively low. (See Fig. 27; March 1936 issue.)

The various distances along the horizontal axis are
appropriately marked according to the difference fre-
quencies. The vertical deflections are produced by ampli-
fying the potentials passed by the filter.[5] In certain
cases a logarithmic amplifier is used for this where the
output potentials bear a logarithmic relation with the
input so that vertical deflections can be designated in
decibels.

Another variation which assists in the analysis of the
oscillograms requires a specially tapered potentiometer
for the horizontal sweep or some similar arrangement,
so that each octave is alloted the same horizontal space,
the same as on a piano keyboard (see page 78, March
1936 issue).

MATERIALS TESTING BY ACOUSTIC METHODS

The determination of non-homogeneity of magnetic
materials has been outlined in a previous section de-
scribing methods whereby fissures or other irregularities
can be located. In some cases it is possible to make
similar checks in non-magnetic materials by using sound
waves. The principle is to introduce either transverse or
longitudinal vibrations in the material. On either side of
the point of application two pick-up devices (which may
be piezoelectric units or phonograph heads) are located
so as to be reliably actuated by the vibrations. A linear
or an elliptical diagram results when those potentials
(amplified if necessary) are applied to the deflection
system, depending upon their relative distance from the
source (measured in parts of a wave-length of the
sound). As the material is moved past this triple unit,
any change in the phase difference due to possible cracks
becomes visible as a change in the shape of the ellipse.

For other items an oscillogram of the sound wave fre-
quency, and its decrement resulting from a blow with a
hammer,[6] will indicate abnormal conditions in temper,
homogeneity, shape, etc. An example of this test deals
with checking marine or aircraft propellers. In such ap-
plications a linear time base is preferable because the
decrement curve is directly reproduced.

GEOPHYSICAL PROSPECTING

The same type of test, carried out on a much greater
scale, is effectively applied in the normal procedure of
some geophysical explorations.[7] Sounds (generally gen-
erated by setting off an explosive charge) are picked up
at one or more receiving positions and are recorded oscil-
lographically. Here the echoes produced by reflections
from strata of different characteristics are used to
measure the depths of those layers, utilizing the values
of the transit time of sound waves, and in some cases
the decrement of those waves. The depth is obtained by
triangulation.

The technique[8] used in these geophysical applica-
tions is largely the outcome of principles worked out in
connection with marine surveys during the war. All such
tests such as submarine signaling, acoustic depth finding,
submarine (and aircraft) detection, direction finding,
etc., are based on similar principles, except for the in-
tervening medium: water, earth or air. While most of
the work done along these lines was accomplished by
using aural detection methods combined with various
types of phase compensation devices, nevertheless in all
cases the amplitude, time and phases of the received
wave trains must be accurately analyzed. Hence the
oscillographic methods have a distinct advantage.

VIBRATION ELIMINATION

The frequency of the vibrational modes found in ma-
chinery is usually in the middle audio range, which per-
mits common types of sound pick-ups to be used. While
deflection-type instruments can be arranged to record
such sound levels, it usually is desirable for balancing
purposes to use two pick-up devices so that the modes
of vibration can be determined by phase studies. While
the general technique in such a measurement is the
same no matter what type of object is under investi-
gation, still certain precautions must be observed.

In some cases a single cycle of the movement occupies
a relatively long duration—seconds or minutes. Such
examples are sometimes found in determinations of wind
strains on tall buildings, performance of low speed air
compressors, and the swaying of bridges. The applica-
tion of seismographic methods can be used to advantage
here. Since piezoelectric devices are usually not entirely
satisfactory at such frequencies (see Fig. 8, June 1936
article) and the usual type of audio microphone may not
be any better, it may be found advantageous to use mag-
netic devices. An excellent arrangement is a suitable
pendulum or a massive weight so balanced as to have
the desired freedom in the plane of vibration, to which
is attached an arm which swings a small coil carrying
alternating current. On either side of this coil two fixed
coils are mounted so as to pick up the field of the first
(movable) coil. If the coils are connected in series op-
posing, the resultant potential is zero as long as the
center coil is stationary. Any movement of the weight
will upset this balance and an alternating current will
result which will pass through an amplifier of the ordi-
nary type. The principle used in the magnetic comparator
(Fig. 5, Feb. 1937) can be used if one of the samples is
free to move by reason of the vibration under investiga-
tion.

At the other extreme super-audible vibrations ("super-
sonic sounds") are becoming increasingly important in
many processes. A cathode-ray oscillograph provides a
useful visual indicator of both frequency and amplitude,
since it is equally effective at all frequencies. A piezo-
electric unit specially designed for the frequency under
test can be used as the pick-up unit. *(To be continued.)*

[5] Hall, A Recording Analyzer for the Audible Frequency Range, *Journal Acoustical Society of America*, Vol. 7, Oct. 1935, Part I, pages 102-110.

[6] Obata, Tests on Brick by Means of Sound, *Journal Franklin Institute*, Vol. 203, 1927, pages 647-659.

[7] Keys, The Cathode-ray Oscillograph in the Measurement of Explosion Pressures, *Journal Franklin Institute*, Vol. [illegible], pages 277-291.

[8] Ewing, Piezo-electric Gage for Ballistic Studies, *Journal Franklin Institute*, Vol. 213, 1932, pages 603-614.

INSTRUMENTATION FORUM

PROBLEMS — SOLUTIONS — DISCUSSIONS

FEBRUARY PROBLEM (No. 4)

Water Hammer Pressure Gage

"Device other than costly oscillograph to register shock pressure in a 12" line when the 12" valve is closed suddenly. Gravity flow; normal pressure at point of measurement 4 lbs. in.$^{-2}$."

85 PRIZE DISCUSSION

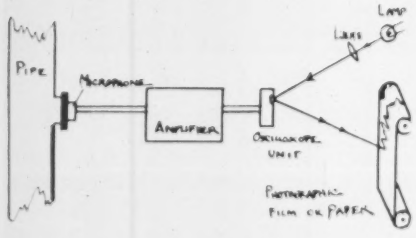
By L. RICHARD LANKES

Since the shock pressure peak probably reaches a fairly high value and yet passes in a short period of time, it is not sufficient to merely indicate it—it must be recorded. Recording naturally means more equipment with a correspondingly greater expense.

Two suggestions are offered:

(1) If the time element involved is not of too short a period, I believe a cardiagraph (as used by the medicos) could be readily adapted for the purpose or, at least, the principle might be utilized, thereby keeping the amount of equipment decidedly at a minimum.

(2) That the value of the use of the oscillograph was realized is apparent in the statement of the problem. If the inertia of mechanical linkages, etc., obviates their use, we come back to considering the oscillograph principle. I believe it can be used while keeping the equipment and expense down fairly well.



The detector device could be some type of piezoelectric microphone available commercially as a "vibration pickup" or "contact type microphone" and at a reasonable price properly coupled to or built into the system. Inexpensive amplifiers are available at the radio supply houses and one could be used in conjunction with the microphone. The output of the amplifier could be used to operate a piezoelectric oscilloscope unit which is now commercially available (Brush Co., etc.) and small in size. One type occupies a space as small as 1" × 1" × 1." and is the counterpart of the galvanometer and mirror unit in oscillographs other than the cathode ray type. The other requisites would then be a suitable light source and a means of having the reflected spot of light expose a moving strip of photographic film or paper.

[Editor's Note—Mr. Lankes correctly locates, in his sketch, the pressure pick-up right next to the 12" pipe, to avoid errors introduced by a length of tubing between the 12" pipe and the responsive element. He fails to give any suggestion for the *installation* of this piezoelectric pick-up. His "solution" is incomplete in this respect but we accept it as a "discussion."]

85 PRIZE DISCUSSION

By H. J. WILMARTH

Before proceeding to methods, two prefatory remarks may be valuable. First, water hammer is seldom a single smooth pressure surge. Unless the main valve is shunted with just the right by-pass, vibrations are set up which travel as waves in the piping, reflected partially at every bend and hanger, until the pressure pattern in time and space is extremely complex. Second, although the destruction is the resultant of very many factors, it is more nearly proportional to the impact or impulse, the product of pressure and time, than it is to the peak pressure.

The simplest possible instrument for studying water hammer is a capillary jet, drawn from glass or selected from a physician's set of hypodermic needles and cut down to fit, set horizontally in the side of the pipe. A horizontal board a few inches below it completes the apparatus. The water will squirt to a maximum distance along the board proportional to the maximum pressure, to a first approximation, and the total volume squirted will be proportional to the impact. If just any jet is used, the results will be crude, but if the jet is selected by some such calibration scheme as that given below, quite passable accuracy is possible.

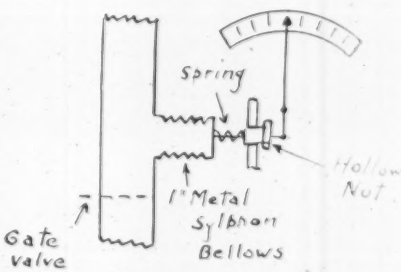
To calibrate, take out the jet after a few trials and connect it to a source of water under pressure, measuring both the rate of flow and the distance squirted as a function of the water pressure up to and somewhat (20 to 30 percent) beyond the peak pressure during the water hammer, as taken by its squirting distance. If the rate of flow is proportional to the pressure all the way up, then the impact and peak pressures as read for the water hammer from the calibration curves are quite accurate. If the rate of flow is not proportional to the pressure, choose a finer, shorter jet.

There are three things to watch: (1) the jets must be smooth inside, with a flaring entrance and thin walls at the other end; (2) the flow through the jet changes about 4% for each degree C. change in the water temperature; (3) in measuring the rate of flow the end of the jet must not be under water but free in the air (this is especially important in the measurements on water hammer). It may also be necessary to use a little loose plug of glass wool to keep dirt and bubbles out of the jet.

85 PRIZE DISCUSSION

By JAMES S. ALLEN

The shock pressure in a 12" line when a 12" valve is closed suddenly may be measured with the apparatus shown in the diagram. A flexible metal "sylphon" bellows is connected to a light pointer. By means of an adjustable spring the pointer may be set at the zero of the scale for any initial pressure. Since the moving parts are light, the pressure gage will follow the pressure wave and if the gage has been properly calibrated, its reading will give the peak pressure.



If continuous readings are desired, a moving tape may be substituted for the scale and a pen point added to the pointer. A pressure wave will then be indicated by a sudden peak in the trace on the moving tape.

[Editor's Note—Such a device need not be home-made; it is commercially available as an indicator or as a recorder. The indicator should be maximum-registering, because of the difficulty of observing by eye the maximum excursion of the pointer. This maximum excursion would be greater for a shock pressure than for a static pressure of equal value. Professor Allen's "solution" is incomplete in this respect but we accept it as a "discussion."]

Problem No. 6 **Subject Index 2.09**

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STRUMENTS' BOOK SHELF

ctrical Engineering Testing. By ASPINALL PARR. Fourth edition, ...ge reissue. Chapman & Hall, London, 1935. Cloth, 5½x8½ inches, xii + 258. Price 8s 6d.

...s book is one of the "I.U." ...useful series intended to occupy a position midway between the ...retical and the purely practical. ...material is systematically arranged ...what in the manner of a laboratory manual, each test being complete ...self and requiring little or no ...-reference. The work is divided ...two main sections: 489 pages on ...ical tests, and an appendix of nearly ...200 pages covering proofs of formulæ, descriptions of instruments and ...equipment, and tabulations.

After the first nineteen tests, which have to do with the calibration of instruments and meters, there are taken up in succession resistance measurement, photometry, and the general testing of electrical machinery and apparatus, including over-all tests on fan motors and engine-generator sets. The fourth (and final) test comprises sixteen pages devoted to the jointing of cables. The tests are for the most part based on sound engineering principles; but the relative prominence given to different types and pieces of equipment reflects the perspective of the latter years of the nineteenth century. The descriptions of test instruments and accessory apparatus would form an effective guide book to a museum of engineering antiquities. A careful study of the descriptive matter fails to reveal any piece of equipment that was not in common use twenty-five years ago. The Rowland and the Siemens electrodynamometers and the Kelvin balance are treated as modern types of instruments and it is apparently assumed that these will be used in the tests outlined. Certain insulation tests are specified as requiring "a battery of Leclanche cells giving an emf. of about 100-200 volts." Many of the units—not presented as antiques but ostensibly illustrating the current models of instruments—may be identified with illustrations appearing in catalogs and textbooks published between 1890 and 1900. Even the Duddell oscillograph and the Evershed megger shown are of the earliest forms to become at all commonly known. Though reference is made to ammeters, voltmeters, and wattmeters, there is nothing to indicate that the author was familiar with these instruments in any form other than the non-portable varieties now long since relegated to the top shelves of laboratories.

Wiring diagrams do not follow any conventional system of representation; and practically no reference is made to the use of shunts or instrument transformers. Though many of the alternating-current tests — particularly the expositions of the performance of elementary a-c. circuits—are well presented, the measurement of alternating power is briefly and awkwardly handled, starting with special cases and attempting to develop a generalization. The one diagram shown as representing the use of voltage and current transformers for the measurement of power in a three-phase circuit illustrates a connection unknown in present-day testing practice, and for whose adoption no sound theoretical basis appears.

No type of wattmeter, other than the single-element electrodynamic type, is mentioned; and the use of watthour meters or recording instruments in testing work is ignored. Of course no reference is made to electronic devices, nor to any form of static rectifier other than the "Nodon valve." A brief description of the steam-engine indicator and of the Amsler planimeter provides a pleasant interlude for the electrically trained reader.

Nomenclature and terminology are not only foreign but archaic; and such terms as "electro-motor," "choker," "thick coil," "inductiveness," "+ve" —"-ve" are profusely used. Most of the illustrations are line cuts; and of the few halftones which appear those which justify a second glance are the exception.

A number of tables useful in electrical testing are appended; but the table of doubled square roots (a copy of that always furnished with the Kelvin balance) is as superfluous as are the lengthy instructions which accompany the descriptions of many instruments, and which might better have been left in the manufacturers' instruction books where they would at least have had the opportunity of being occasionally brought up to date.

Though this book bears the imprint of 1935, it is observed that the latest edition is dated 1922. Little in the contents of the book, however, would indicate development to that date; and it is felt that if the text were stripped of all material not known in the electrical engineering field at the time of the first publication (1901) the work would lose but few of its pages.

—PERRY A. BORDEN, *Research and Development Engineer, The Bristol Co., Waterbury, Conn.* (41-B-

Cathode Ray Oscillography. By L. T. MACGREGOR-MORRIS and J. T. HENLEY. Instruments Publishing Co., Pittsburgh, 1936. Cloth, 5½x8¾ inches, xiii + 249 pages. Price $6.00.

This book is one of the first English presentations of the important phases of this versatile development in the field of electrical measurements. Its style is such that it makes an excellent textbook for either classwork or home study in this branch of electronics, or a handbook for general reference.

Herein will be found a general outline of the whole field of electron-ray oscillography, from the fundamental principles of the tube to details of many applications in engineering fields. The authors make no claim to furnishing complete and detailed information on either the design of tubes or on the construction of the associated apparatus, but they give all necessary information to enable the reader to make intelligent use of cathode-ray tubes and to systematize such tests with due regard for inherent advantages and limitations.

The book bespeaks a long experience in this field. The senior author, in fact, has long been known; his book-length paper in the *Journal of the Institute of Electrical Engineers* (1925) is a classic work on the subject. This experience has enabled the authors to avoid the inclusion of non-important and controversial matter, maintaining strictly the style of a text and reference book.

Scientific progress in all branches of engineering has been largely due to the science of measurements. At one time quantitative determinations of the various electrical magnitudes were considered sufficient. Of late it has become evident that time relations must be considered as well, so that phase differences and the inter-relation of the separate factors must be studied, whatever those factors are—forces, displacements, electrical magnitudes, etc. This accounts for the popularity of the oscillographic method for all types of development tests, and shows why this specialized field of measurement should be accorded so much attention in the "Monographs on Electrical Engineering," of which this book is Volume II.

Starting with the fundamental principles involved in the design of C-R tubes, the authors review the properties of cathode rays and the control of their movements. A chapter is then devoted to focusing methods, including the modern electron lens principles, and the major problems associated with electron optics. Two chapters then take up specific types of tubes and their particular features, one dealing with the high-voltage cold-cathode tubes used in the delineation of transients and other phenomena associated with high tension circuits and lines, and the other with the types using heated cathodes and lower anode potentials. Chapters then follow on the principal uses and operation of each of these types for oscillographic work. Chapter 10 for example is of special interest, dealing with the many appli-

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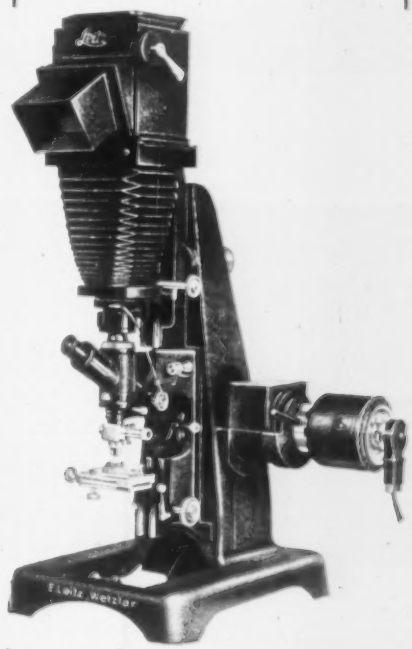

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cations that have been found of value, using the modern low-voltage hot-cathode tubes.

Two chapters are included on auxiliary apparatus, one on voltage sources, vacuum pumps, photographic equipment, etc., and the other on time-base circuits of various types, including several interesting arrangements that are popular in Great Britain. The performance and limitations of cathode-ray oscillographs receives attention in another chapter, taking up matters that have received scant attention in many places. In conclusion a section is devoted to a discussion of the applications of cathode rays to television, setting forth the principles involved and a description of the various methods in use. A selected bibliography enables the reader to follow up with outside reading the particular subjects of interest.

Many of the popular American tubes are not included, but the operation and application of those that are described can be readily adapted to equipment available here. The diagrams are excellent, and the photographic details clear-cut by reason of the insertion of numerous pages with photographs and oscillographs reproduced on glossy paper. It is timely for the publishers to have made this work available to American readers.

R. R. Batcher, *radio engineer, cathode-ray application specialist, Hollis, L. I., N. Y.*

(5-41-B-

Dielectric Phenomena in High Voltage Cables. By D. M. Robinson. Instruments Publishing Co., Pittsburgh, 1936. Cloth, 5½x8¼ inches, 173 pages. Price $5.00.

This book is a monograph of a series sponsored by the I.E.E. of Great Britain. It is of interest to compare this book with one of similar subject-matter, "Impregnated Paper Insulation" by J. B. Whitehead, which is a monograph of a series sponsored in this country by the Committee on Electrical Insulation of the National Research Council.

These two books make suitable companions by reason of their supplementary character; and also because of the difference in the viewpoints and in the development of the subject-matter. There are, in general, two methods in the studying and improvement of a product. One involves the determination of properties, either under ideal conditions or under conditions which are modified in certain limited and controlled manner. The other method starts from the finished commercial or semi-commercial product and determines the causes of weaknesses actually existing. Both methods are valuable. In fact, both methods must be pursued simultaneously in order to make the greatest advancement of knowledge and development in a particular art. Thus, there is great value in studying together these two books, the one by Dr. Whitehead dealing primarily with the first method and this new one dealing with the second.

The author's remarks on page 129 are in point and are here quoted:

"Attempts are often made to obtain the necessary information [on cables] from tests on flat sheets of material between brass or tin-foil electrodes. Such 'condensers' are generally well dried and impregnated, and there are no voids, with the result that the breakdown stress is many times the best value obtainable with a straight type cable having the same dielectric. This discrepancy makes it difficult to place any confidence in the method [as applied to cables]. The same remarks apply to the testing of laboratory cable models as carried out, for example, by Whitehead."

"Probably the most outstanding difference between laboratory cable models and actual "solid type" cables lies in the "voids" which are absent in the former and always present in the latter. The heating of the cable due to the load causes the saturating oil to expand, and the lead sheath becomes distended to accommodate the additional volume of oil. When the load is removed, the cable cools and the oil resumes its original volume, but the lead sheath, being inelastic, retains its distended size. Thus, spaces, commonly called "voids," remain in the these "voids" containing gas or at a pressure which may be mu low atmospheric. Even unused type cable is not wholly free of "v In some of the newer types of (Oil-Filled, Oil-O-Static, etc.) tion of voids is effectively elimi but even in these it is probabl minute "voids" far smaller tha found in "solid type" cables do The author concentrates his att on the effect of "voids."

The book devotes much space t author's theory of the "tracking" of failure, which he states is the usual type of failure in presen "solid type" cables. This theory first propounded by the author paper, "The Breakdown Mechanis Impregnated Paper Cables" appe in the *Journal of the Institution of Engineers* in July 1935 (Vol. 77, pa in which the theory is fully describ The present book again describe theory and places it in proper pe tive with reference to the entire ject. Other types of failure are cussed as well as other theories have been advanced in explanation cable failure. Wagner's pyroelec theory of breakdown, which has extensively discussed, is analyzed w reference to cable insulation and i futed. The clear and concise anal shows effectively that normally, cable dielectric, there is no room this particular pyroelectric theory

From the large mass of cable failure data which have been obtained by engineers in recent years, it has come to be recognized increasingly that some such mechanism as that described by the author is significant in cable failure. The author has taken this mass of largely disconnected data, augmented by a great deal of well planned data of his own, and from them has evolved his "tracking type" theory of cable failure, which, on the whole, is sound and reasonable, and constitutes a valuable contribution to power cable engineering.

A great deal of interest in the theory has been evidenced by British and American engineers, and the reviewers believe that there is a general acceptance of most of the theory as expressed by the author. There are parts, however—and important parts—of the theory of this mechanism which are not accepted as generally as might be understood from the monograph. We would make a distinction between the type of statement appropriate in a paper and one appropriate in a book. The former is properly the statement of new thought and of the opinions of the author, whereas the latter should either tend toward being the considered opinion of the group informed on the subject or should state that it is limited in authority to the author's opinion. While the "tracking type" theory has developed a great deal of discussion and interest among British and American engineers, there are essential parts which still remain open for futher discussion and should appear in such a monograph as this with due qualification. In short, our criticism on this point is that, useful as is the theory, and general as is the acceptance of much of it, the claims for its completeness and accuracy are broader than is fully justified.

An additional danger in making unnecessarily broad claims for new theories lies in the fact that if later the theory is found not to apply in some special case there will be a tendency to discredit the entire theory. For example, it is stated that in order to start the mechanism for the tracking type of failure in single conductor unshielded cables, ionization must occur at one of the electrodes; that ionization in the body of the dielectric, no matter how severe, will not start this type of failure. It is stated further (page 81) that the breakdown of belted cables differs from the single core cable only in matters of detail. Now, it is well known that in belted cables failures sometime begin in the filler space at the center of the cable, where large tangential stresses occur. The stresses at this point are so great as to cause vigorous "sparking and glowing" which cause carbonization and in some cases lead to failure by a mechanism very similar to that described by the author. Without proper qualificati

1854 — Elihu Thomson — 1937

Professor Elihu Thomson, dean of electrical engineers and American scientists, one of the founders of the General Electric Company, died at his home in Swampscott, Mass., March 13. Eighty-three years old, he had been seriously ill since January. Funeral services were conducted in Lynn, Mass., where there is located the Thomson Research Laboratory of the General Electric Co., named in his honor, and of which he had been Director for fifteen years.

Elihu Thomson was one of America's great pioneers in the field of electrical science. His name was given to the Thomson-Houston Electric Company, organized in 1883, and merged in 1892 with the Edison General Electric Company to form the General Electric Company of today, with which he had been associated ever since. He was one of the most far-sighted of the early arc-light inventors, and experimented with the principle of alternating current transmission far in advance of commercial demands. He held upward of 700 patents in the United States alone. He originated the resistance method of electric welding, which has been in continuous use from 1887 to the present time; developed the repulsion type of induction electric motor; invented the magnetic blow-out principle in lightning arresters and electric switches, the oil-cooled type of transformer, the constant-current transformer, and the modern process of commercially treating fused quartz. There was scarcely any aspect of electrical science in which Thomson had not been active at some time. More than ten years before Hertz in Germany discovered the electromagnetic waves of radio Thomson was demonstrating, in 1875 at Philadelphia, the transmission of signals without wires. He originated the three-phase electric dynamo machine in 1879 and anticipated experimentally, in the same year, the modern practice in transformer work. He invented the first practical wattmeter, thereby winning half of a Grand Prix at the Paris International Exposition of 1889.

Outside of electrical matter he was also active. With Professor Houston, he invented in 1877 to 1881 the continuous centrifugal separator and the laboratory centrifuge. He patented in 1903 a non-condensing reciprocating engine which became the "uniflow" engine; and he devised the fused quartz mirror for astronomical telescopes nearly forty years ago.

His life-time hobby was astronomy, in which he was active as an amateur at an early age. He was also interested in microscopes, autochrome photography, and in building and playing pipe organs. He had a host of friends in scientific and engineering circles, not only in America but in Europe, particularly in England, the land of his birth.

Professor Thomson was the only man who ever received all three of England's highest scientific honors: the Hughes, the Lord Kelvin, and the Faraday medals. He also had the medal of the Verein Deutscher Ingenieure, the John Fritz medal from the four leading American engineering societies, and the medals of the Franklin Institute, the American Academy of Arts and Sciences and the American Institute of Electrical Engineers. He was president of the International Electrical Congress in 1901 and of the Electrochemical Congress in 1940 and 1941. At one time he was vice president of the American Academy of Arts and Sciences and vice president of the American Philosophical Society. He belonged to innumerable engineering societies all over the world.

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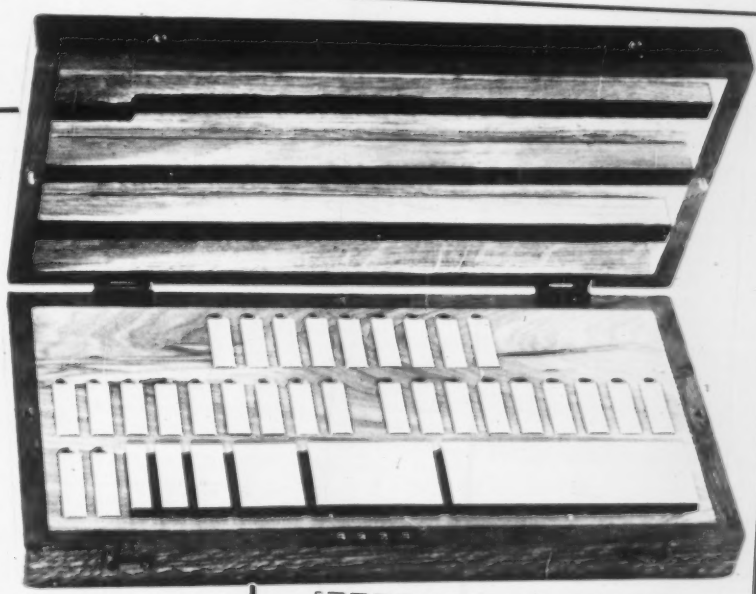

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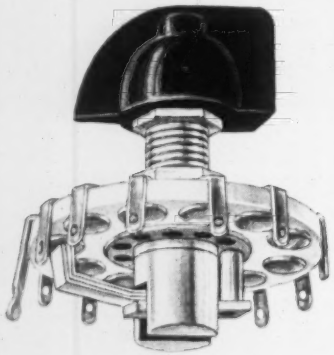

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the statements made in the book are therefore not strictly accurate.

Aside from somewhat too great generalization in some cases, the book is a valuable contribution to the published literature on high-voltage cables. The experimental data given are of high order, descriptions and criticisms are well thought out and concisely expressed, and the whole is written in a clear, interesting style.

Among several things of special interest to American engineers might be mentioned the comparison of 50- and 60-cycle operation. The breakdown strength of cables at 50 cycles is indicated to be 10 or 15% greater than at 60 cycles (Fig. 87), and the problem of adequate terminals is said to be much greater for the higher frequency. While, of course, it has been recognized in this country that a frequency of 25 cycles is more favorable than 60 cycles, there has been no previous suggestion that there is an important difference between 50 and 60 cycles. In this connection the following quotation from page 149 will be of interest: "The fact that both coring and tracking are affected by frequency in this way probably accounts in part for the greater difficulties experienced in the U. S. A. where the frequency is 60 cycles, as against Europe where 50 cycles is the rule. Cable engineers should be thankful that 100 cycles did not become standard!"

R. W. Atkinson and L. Meyerhoff, *High Tension Laboratories, General Cable Corp., Perth Amboy, N. J.*

(4.1)-B-

Principles of Electric and Magnetic Measurements. Part I, Electricity, by P. Vaucrein; Part II, Magnetism by C. E. Webb. Prentice-Hall, Inc., New York, 1936. Cloth, 6 × 9 inches, xii + 392 pages. Price $5.00.

Each of the two authors is a distinguished physicist at the National Physical Laboratory of England and each has produced a treatise worthy of that institution's highest traditions: thorough, comprehensive (except for some non-British and for some industrial instruments), essentially mathematical, scantily illustrated and written in a severely terse style.

This is especially true of Part I. Of its 274 pages, we believe that there are not more than a score (scattered, not consecutive) which can be assimilated at one reading by "the average American engineer" who can read and absorb page upon page of most American texts on electrical measurements without even having to pause to let a formula sink in. In short, it is "hard to read."

But the unfairness of "hard-to-read" as a complete characterization gradually dawned on the reviewer's mind as he devoted some twenty hours—not at a stretch!—to this "hard reading." Perhaps we can best explain by relating one typical experience.

Desiring to make a special study of the section on cathode-ray oscillography and deciding (after a glance at the Table of Contents) that we should start with a preceding section on "Motions of Electrons in Electric and Magnetic Fields," we did so. Here is the way this section abruptly opens:

"Take rectangular axes x, y, z, and consider a uniform magnetic field B webers per sq. metre in the direction of y, bounded by $x = 0$ and $x = \xi$ . . ."

Then an exposition involving twelve equations, and finally, in the conclusion, ". . . the ion moves in the xz plane along a parabola of latus rectum $2mU^2/Xe$ with vertex at O and axis Oz. . . . an angle of $Xe\xi/mU^2$, as can be easily verified from the geometry of the parabola . . ."

And not a single diagram for either the magnetic or the electric deflection principles! More than hard to read: hard to study, especially for "the average American engineer" who can't visualize analytical geometry problems in his mind the way some European-university-trained engineers seem to do with the greatest of ease. But candor compels the admission that (after paying the price of mental sweat) we were richly rewarded by a clearer understanding of deflection principles than we ever had. And it probably will "stay put" until the gray cells disintegrate in the grave. Which is seldom true of "easy reading."

The same can be said of nearly all the 108 other sections of Part I. These 109 sections represent its real [illegible] arrangement, but for convenien[illegible] are made up into eleven chapt[illegible] ginning with "Units and Stand[illegible] and including all major subject[illegible] lated to the underlying theory [illegible] classes of electrical measurement[illegible] struments as such—their constru[illegible] maintenance, etc.—are usually dis[illegible] of with brief generalities, among[illegible] few exceptions being galvanom[illegible] which receive a treatment worthy [illegible] book on instruments. This is to b[illegible] pected in a work written for phy[illegible] rather than for engineers. To list [illegible] contents of Part I would require [illegible] much space here. Suffice it to mention that the 109 sections cover not only [illegible] customary electrical measurement[illegible] transformers, electrolytic capac[illegible] screen-grid tetrodes, X-ray diffraction, and Planck's h. Every electrical [illegible] search laboratory should have this monumental treatise.

And no magnetic research laboratory can afford to be without this book, if only to have at hand Part II. Its 112 pages—much more easy to read than Part I—contain some sixty or eighty "sub-sections" (the topical arrangement being rather complex) covering all classes of magnetic measurements with what seems to be an emphasis on ballistic methods and toward the end on magneto-electric and magneto-optic effects. In this Part the instruments are discussed as such, about one-third of the entire text dealing with their proper setup, their characteristics, etc., and the illustrations giving more than a sketchy idea of the arrangement. Moreover, the author does not hesitate to compare various methods with one another, as in discussing the Epstein, the Lloyd-Fisher and the Chattock sheet-material testers.

Throughout the book there is a sprinkling of Anglicisms ("belt of frequencies," etc.) but none obscuring the meaning. More serious is the profusion of vague expressions such as "very small," "highly accurate," "almost exactly 1 ampere," etc. Part I abounds in these. In Part II these seem to have been "spotted" in the final editing, as on page 369 where "very small changes in length" was probably the original wording and "changes in length of the order of 10^{-7} cm." wisely substituted. As we have preached for "very many" years the word "very" shouldn't [illegible] be used in a book on measurement.

—M. F. Behar (1)-B-

Electrical Measurements and Measuring Instruments. By E. W. Golding. Pitman Publishing Corp., New York. Second edition, 1935. Cloth, 5½ × 8½ inches, 812 pages. Price $6.00.

The first edition (1933) was merely one of the "Engineering Degree Series." It covered the syllabuses of certain English examinations. As the work progressed—according to the author's preface—it outgrew the original scope and became a volume suited to the requirements of electrical engineers in general and more particularly of those engaged in standardizing and metering. The present edition adds material on Symmetrical Components, and on recently-developed measurement uses of rectifiers, photocells and electron tubes.

In the opening chapter the subject of electrical and magnetic magnitudes, their significance, and their quantitative determination is viewed from the standpoint of the physicist; and the elementary concepts of the units are treated in accord with generally accepted physical theory. The reader who makes an analytical study of this chapter cannot but leave it with his knowledge of basic electrical determinations refreshed. In the second chapter are explained the fundamental units of electrical measurement, including the mechanical embodiments of those units for practical standardization. This is followed by a chapter on various symbolic representations, including revolving vectors, complex quantities and symmetrical components. Several sections provide a thorough discussion of capacitance, inductance, and resistance with, many examples of the calculations of circuits possessing these properties either alone or in combination. A number of bridge circuits and direct-indicating instruments for measuring these properties are fully described.

A chapter on d-c. and a-c. potentiometers covers essential theories in considerable detail and describes several typical networks. Actual examples, however, with one exception —

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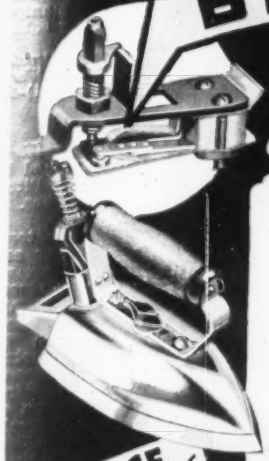

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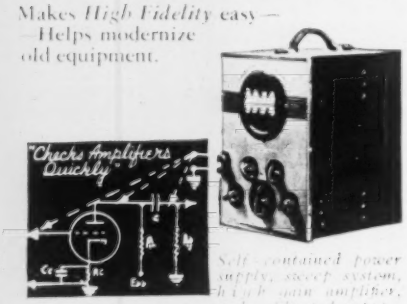

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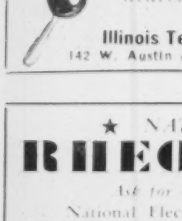

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Brooks deflection potentiometer—are confined to descriptions of British and Continental models of the instruments. Fifty-five pages are devoted to the subject of magnetic measurements, including both unidirectional fields and alternating magnetic phenomena, as well as a comprehensive discussion of iron-loss determination, and descriptions of a number of practical methods by which magnetic magnitudes may be determined. Eddy currents receive a treatment to satisfy the most exacting reader.

Rapid advances in the theory and technique of high-voltage measurement are reflected in the author's admission that his chapter of 41 pages is far from complete, and in his referring the reader to the ample bibliography for fuller discussions. Localization of cable faults is treated more fully than is usual in texts of this nature, and many useful tests are described and explained. The chapters on wave forms and transients are essentially mathematical, rather than practical; and more attention is given to the analysis than the determination of these quantities. Several contact methods of wave-form determination are outlined, and essential principles of electromagnetic and electrostatic, as well as cathode-ray, oscillographs are shown in detail.

A broad discussion of the basic principles of electrical measuring instruments occupies one whole chapter, in which are introduced some unusual concepts. Instead of following the conventional method of considering the moving element of an instrument as subjected to the action of *two* opposing forces, the author includes damping, making the number of forces *three*. It is doubted that such a consideration of damping (which in itself has no effect on the ultimate accuracy of an instrument) as one of the primary forces, materially clarifies the treatment. In discussing damping, the author consistently discriminates between air damping and "fluid" damping. Recording instruments receive brief notice, little distinction being made between direct-marking and relay-types of instruments.

In the treatment of current, potential, and power measuring instruments there is observed a perspective decidedly different from that of the American reader, particularly in the prominence given to indicating instruments of the induction type. Some confusion between thermocouple and hot-wire instruments is apparent. As might be expected in a work emanating from a British source, electrostatic instruments are discussed with thoroughness and accuracy. Instrument transformers are considered in detail, and their operating principles, together with all possible sources of error are well discussed. There are described a number of devices and methods for checking accuracy and compensating for errors.

Under the heading of energy measurement, while what appears to be undue attention (six pages) is given to obsolescent meters, it must be admitted that this material is interesting and instructive, and also that present-day types of meters—induction, mercury-motor, and commutating—are not neglected. Demand measurement and totalizing are barely touched upon, some of the best known and most effective devices for these purposes receiving no attention whatever. Volt-ampere determination and the measurement of frequency and phase-displacement receive their due allotment of space.

Two chapters—one on illumination, and one on temperature measurements—deal with these highly specialized subjects in a sketchy manner. Though the shortcomings of the text in this regard are to a degree made up by the bibliographical references, neither treatment can be considered as complete or up-to-date; and, since these magnitudes are not primarily electrical or magnetic, the inclusion of these chapters in the book does not appear justified.

It is logical that the work—primarily a textbook for use in educational institutions—should close with a group of examination questions. 129 of these, drawn from various British sources, provide a decidedly comprehensive cross-section of the whole art of electrical instrumentation. The book is illustrated with 147 line drawings, diagrams and curves interspersed with a few halftones illustrative of specific instruments and their component parts. More than 500 numbered bibliographical references, drawn from widely [illegible] ated sources, appear as footnotes [illegible] respective chapters.

Any shortcomings which [illegible] noted in the perusal of this [illegible] more than offset by its thoroughness and accuracy in the most important features of electrical measurement. The work should go far to bridge the gap between the purely theoretical mathematical treatment of electrical measurements, and the definitely practical text for the "practical" man, to whose lot falls the use and maintenance of measuring and testing equipment.

—P. A. Borden, *Research and Development Engineer, The Bristol Company, Waterbury, Conn.*

(12) B-

How to find Metallurgical Information. By Richard Rimbach. Published by the author, 1117 Wolfendale St., Pittsburgh, 1936. Paper, 8½x11¼ inches, 32 pages. Price $1.00.

When we have to deal with a [illegible] with which we are not familiar [illegible] need to start from the ground up. We think "I wish there was a good recent book on this particular subject. Maybe there is, and we just don't know about it. This pamphlet, with its author and subject index of metallurgical books available to August, 1936, will let us know about it. Moreover, it gives concise information on metallurgical handbooks, periodicals, abstracts, services, patents, specifications, buyers' guides, lists of trade names and statistics. It also recognizes the fact that useful metallurgical information is available in company periodicals and in company literature, though the last deals chiefly with book or large pamphlet publications put out by individual firms and could be considerably extended.

The pamphlet will be a boon to technical librarians and to those beginning to search metallurgical literature. Even those who have been steeped in metallurgical literature for years will find that a good deal exists that they are not familiar with and which may hold just the information they want but have not found. It should prove of real utility.

—H. W. Gillett, *Director, Battelle Memorial Institute, Columbus, Ohio.*

(12) D-B-

Le Travail des Verres d'Optique de Précision (Precision Optical Glass Working). By Colonel Charles Dève. Revue d'Optique Théorique et Instrumentale, Paris, 1936. Cloth, 5½ x 8¼ inches, 372 pages. Price 18 frs.

It should be said at the start of this review that the precise working of optical elements is a strictly technical subject. No optical worker can learn his trade from a book. Practice and practice only can teach him what he needs to know. But one must admit in all fairness that this volume offers much help in the practical operations of making precise surfaces on glass. Nothing like it has come to the attention of this reviewer either in English or German.

The first paragraphs of the author's preface read as follows: "To profit from the reading of this book one must be familiar with the tools and the routine operations involved in working glass. An elementary knowledge of optics and mechanical principles is also necessary. Modern practice is not described because the description and analysis of all the different machines for glass working belong in a special treatise. This is not a manual for beginners. It is rather a textbook for one who is master of his trade."

The book is not difficult reading for anyone who has an elementary knowledge of French, for Col. Dève knows his own language as well as he knows optics. He includes a short glossary of technical terms that is extremely useful.

Col. Dève has had a long career in Optical Engineering, was the founder of the "Atelier d'Optique de l'Artillerie à Puteaux," and directed the installation of all equipment at the school for optical workers there. His long experience in the workshop has shown the author all the manifold tricks of the trade. He has thought them through and sought reasons for them in theory with the result that his book presents

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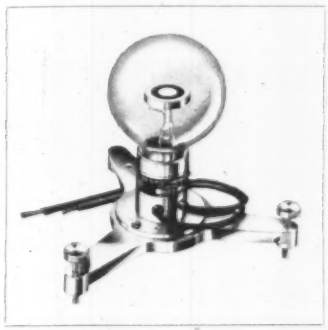

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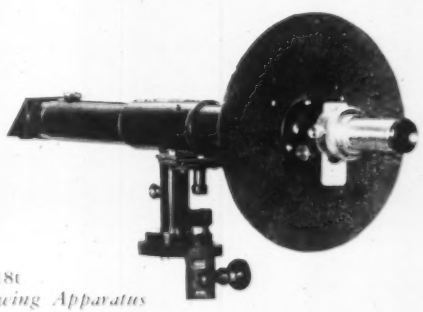

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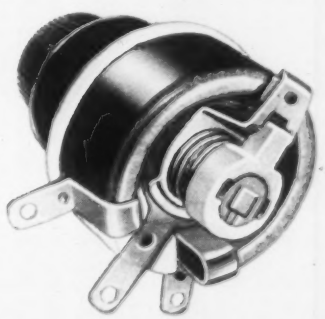

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